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The Journal of the American Welding Society

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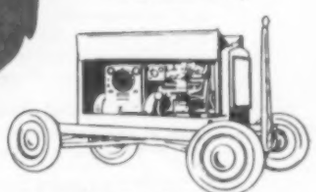

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MAY, 1946

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Welding Engine Bed for 43 In. Rolling Mill. *Courtesy A. O. Smith Corporation*

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Electrodes for Welding Chromium-Molybdenum Steel

By D. L. Mathias* and G. M. Leigh†

TWO series of arc-welding electrodes for the joining of chromium-molybdenum steel have been developed. The following discussion will provide a description of the welding characteristics and the essential properties of these electrodes. A range of physical properties and composition of the deposited weld metal will be shown combined with a degree of usability to form a combination which previously has not been available. This development has grown out of a current problem in the field of power piping.

Use of carbon-molybdenum steel for power piping and arc welding electrodes depositing metal of similar analysis for joining such piping has become well established over the last decade. In the past few years the phenomenon of graphitization as a potential cause of failure has been subject to investigation. Previous exploration[1, 2, 3] was concentrated on plain carbon steels and some information was obtained on graphitization and the factors influencing it. Early in 1943 an important failure[8] in a molybdenum steel steam piping system occurred which was attributed to graphitization. Added impetus was thus given to study of the subject [4–7] and additional data collected. There is evidence to indicate that the tendency to graphitize is greater in certain molybdenum steels than in many plain carbon steels[8] which is confusing when it is remembered that carbide-forming elements, such as molybdenum, are generally considered to contribute to increased carbide stability. However, the results in general indicate that the presence of elements forming more stable carbides will combat graphitization. Limitation of the aluminum additions used to deoxidize the steel originally has an effect in reducing graphitization. It has been suggested that the carbon content of the steel be reduced to a point where graphite nucleation is negligible in the lifetime of the pipe[9] but this increases the cost of the material and accentuates the control problems in the open-hearth furnace during manufacture. In addition, it necessitates use of other deoxidizers to produce a sound steel. This may influence grain size and be detrimental to the creep strength of the steel at elevated temperatures.

A possible solution has been found in utilizing chromium-molybdenum steels in place of carbon-molybdenum. Addition of chromium as an alloying element provides greater stability in holding the carbides and preliminary tests have indicated successful inhibition of graphitization by this step.

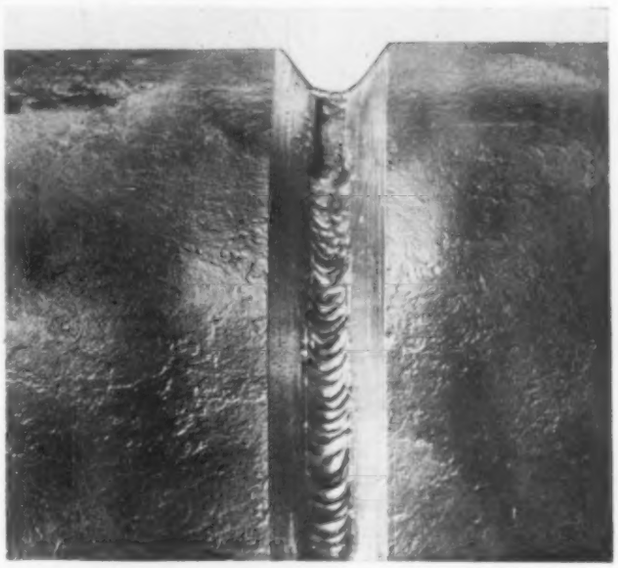

Fig. 1—Photograph of Root Pass in Welding 6-In. Molybdenum Steel Pipe

Transition to chromium-molybdenum alloys for high-pressure high-temperature piping and other alloy steel fabrication creates a need for welding electrodes which will deposit metal of similar analysis and performance.

The Electrodes

To meet this need two lines of electrodes have been developed on two base coatings. One is a rutile type coating whose use classification falls under A.W.S.-A.S.T.M. EXX13. The other is an organic coating covered by A.W.S.-A.S.T.M. EXX10. A low-carbon steel core wire is used throughout. Alloy additions are made through the coating and are available, on both bases, to deposit a chromium-molybdenum alloy in a range of analyses covering the field of application. All-position welding characteristics give maximum flexibility. The XX10 base is used with direct-current reverse polarity. It is recommended that direct-current reverse polarity be used with the XX13 base although good performance is obtained on straight polarity and alternating current.

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† Research Engineer, Metal & Thermit Corp., Research Laboratory, Rahway, N. J.

Fig. 2—An XX13 in Use; Welding Two Sections of 6-In. Pipe in the Overhead Position

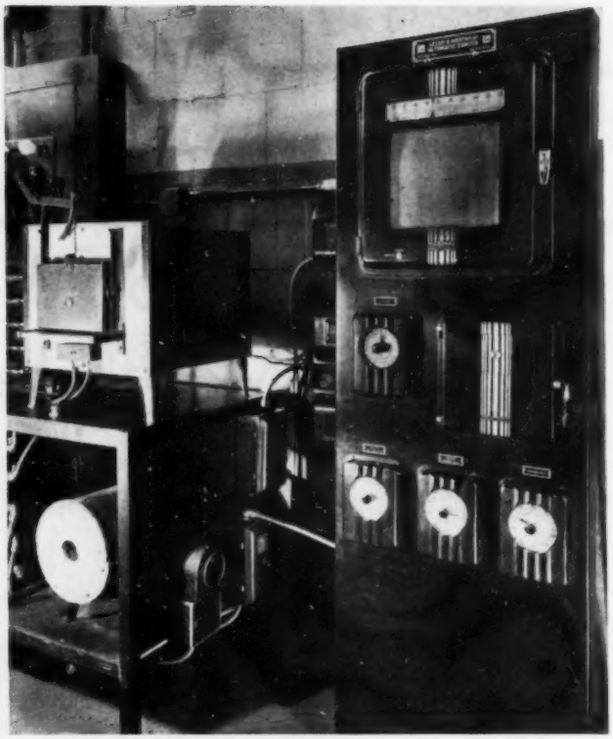


Fig 3—Leeds & Northrup Micromax Automatic Program Controller and Ovens Used for Heat Treating and Stress Relieving of Test Specimens

The XX10 base gives a "hotter" electrode with a higher arc voltage and greater penetration. As is often the case, the XX13 base has greater arc stability than the XX10. The welding characteristics and usability of both bases are good. Factors of weld surface, weld shape, spatter, slag action, slag removal, undercut, reaction pitting (surface porosity) and arc action are at favorable levels. Figure 1 shows part of the root pass welded in the vertical position while joining two sections of 6-in. molybdenum steel pipe.

These electrodes are useful both in field and shop fabrication. Utilization is indicated in power piping, oil-field equipment, process equipment, and a wide variety of alloy construction. Figure 2 illustrates an XX13 in use; welding two sections of 6-in. pipe in the overhead position.

The $^3/_{16}$-in. diameters are included in the claim for all-position welding characteristics. However, the $^3/_{16}$-in. should never be used for the root pass in out-of-position welding, especially in the various butt joints with thin plate and back-up represented by pipe welding. Difficulties of slag control and burning through will be encountered making this larger diameter difficult to handle. This is considered poor practice. The $^1/_8$-in. diameter is usually used for the root pass in quality work. The established practices in handling the electrode apply. Vertical welding should be in the "up" direction for best results and a normal to short arc length is used. The flux coating must not come in contact with the parent metal or the molten pool. Straight progression with slight weave to a full weave may be used. Relatively little "whipping" is ever required. Wide weave should be avoided if X-ray soundness is a major factor. In any manual arc-welding operation the use of wide weave can be carried to a point where the arc is not played on any one area sufficiently long to permit the escape of gases from the weld metal at that point before solidification. Gases or slag trapped by the solidifying metal are retained in the weld as porosity and inclusions with a proportionate reduction in weld quality.

The composition of the deposited weld metal has been controlled to provide analyses from 0.5% chromium 0.5% molybdenum to 2.0% chromium 1.0% molybdenum in 0.5% increments of each element. The alloy contents fall into groups as follows:

Table 1—Chemical and Tensile Properties of Cr-Mo Alloy Steel

Material	C	Mn	P	S*	Si	Cr	Ni	Cu	Mo
Wrought (pipe)	0.15 max.	0.30–0.60	0.04 max.	0.045 max.	0.30–0.60	0.80–1.10	...	...	0.45–0.65
Cast (Valve bodies)	0.20–0.30	0.40–0.70	0.05	0.06	0.25–0.55	0.40–0.70	1.00 max.	0.25 max.	0.40–0.60

Yield point, 30,000 psi. min.
Ultimate strength, 60,000 psi. min.
Elongation in 2 in., 30%
Stress relieved 1 hr. at 1150° F.

Designated	Limits
0.5% Cr	0.40–0.60% Cr
0.5% Mo	0.45–0.65% Mo
1.0% Cr or Mo	0.90–1.10% Cr or Mo
2.0% Cr	2.00–2.50% Cr

To simplify the identification of the many electrode varieties made possible by this approach, it is proposed that a generic system of naming the electrodes be adopted. Each variety might be identified by a four-digit number. The first digit would give the amount of chromium in the deposited weld metal in the ratio of one whole number for each 0.5% increment of alloyed element. The second digit could then perform the same service for the molybdenum content of the weld metal. The last two digits would be those of the A.W.S.-A.S.T.M. use classification and identify the base coating of the electrode. In this way, a chrome moly No. 4213 electrode would have an XX13 base and deposit weld metal containing 2.0% chromium and 1.0% molybdenum within the limits indicated in the preceding tabulation. In

Table 2—Physical Properties of All-Weld Metal Tensile Specimens

Prepared in Accordance with A.W.S.-A.S.T.M. Spec. A233–45T
Stress Relieved One Hour at 1150° F.

Electrode	Yield Point (psi)	Ultimate Strength (psi)	Elong. in 2" (%)	Reduct. of Area (%)
3/16" Type 1110 0.5% Cr 0.5% Mo	66,500 64,000	78,000 77,500	18.0 21.9	46.8 64.4
3/16" Type 1113 0.5% Cr 0.5% Mo	78,500 81,500	92,500 95,000	21.1 20.3	55.5 51.1
3/16" Type 2110 1.0% Cr 0.5% Mo	75,500 77,000	90,500 92,000	19.6 18.0	55.5 43.9
3/16" Type 2113 1.0% Cr 0.5% Mo	90,500 91,000	105,000 105,500	17.2 19.6	47.5 52.2
3/16" Type 4110 2.0% Cr 0.5% Mo	81,500 84,000	98,000 99,500	18.8 16.4	49.8 49.5
3/16" Type 4113 2.0% Cr 0.5% Mo	105,500 104,500	122,500 121,000	11.7 13.3	35.0 32.5
3/16" Type 4210 2.0% Cr 1.0% Mo	88,000 97,000	112,500 114,000	16.4 16.4	51.9 51.4
3/16" Type 4213 2.0% Cr 1.0% Mo	96,000 90,000	138,500 123,000	15.0 15.0	46.6 46.6

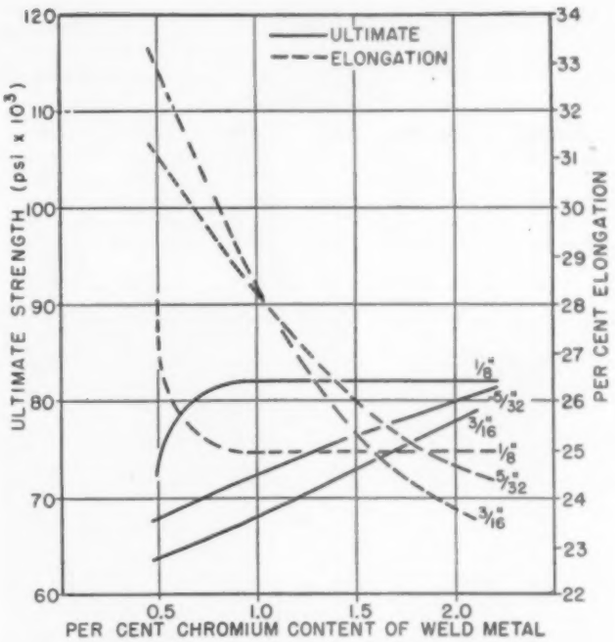
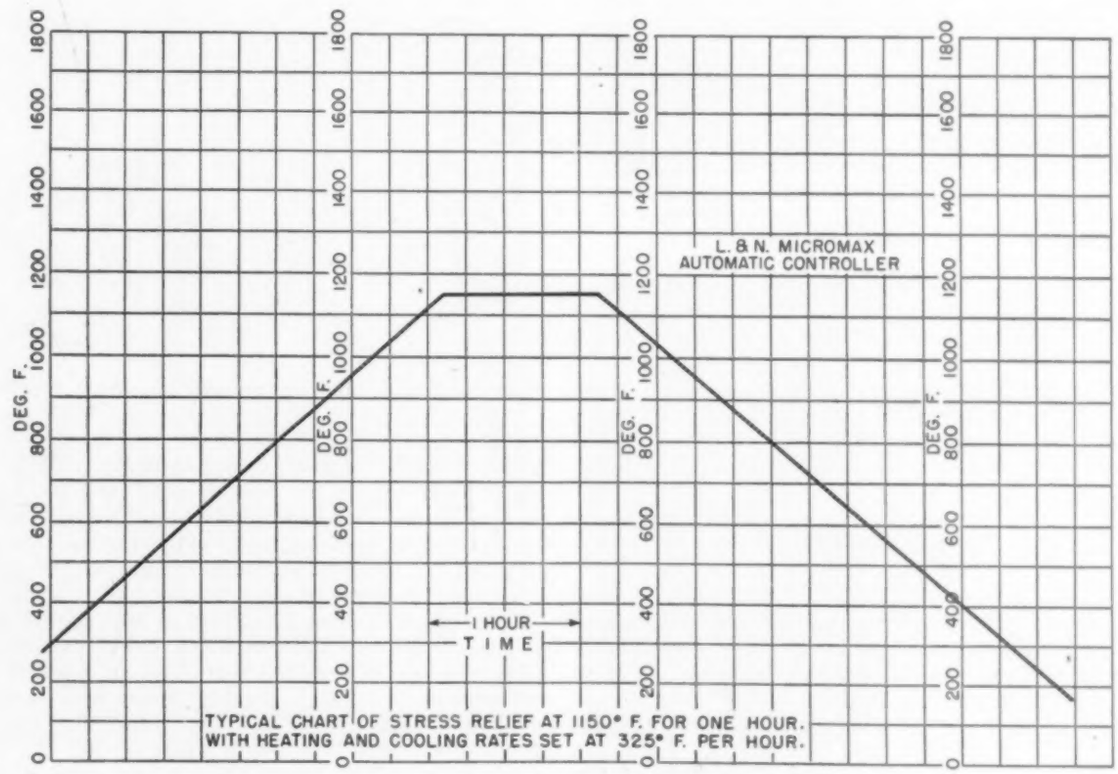


Fig. 5—Relation Between Physical Properties and Chromium Content of Weld Metal Deposited by Chrome-Moly Electrodes with A.W.S.-A.S.T.M. XX10 Base Coating. Molybdenum Content Held at 0.5%. (Specimens Stress Relieved at 1300° F. for 2 Hours)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WITH HEATING AND COOLING RATES SET AT 325° F. PER HOUR.

Fig. 4

Table 3

Diameter	Electrode	Welding Current Direct Current Reverse Polarity Amps	Volts	Physical Properties Yield (psi)	Ultimate (psi)	% Elong. in 2"	% Reduct. of Area	Fracture	Deposit Analyses (%) C	Mn	Si	Cr	Mo
1/8 x 14"	Type 1113	110	20.0	64,000 62,000	82,000 82,000	23.4 25.0	64.4 63.4	1/2 Cup 1/2 Cup	.117	.33	.35	.48	.61
5/32 x 14"	" 1113	150	23.5	73,000 69,000	84,500 83,000	27.3 27.3	61.7 63.8	Full Cup Full Cup	.125	.33	.32	.45	.56
3/16 x 14"	" 1113	180	22.0	73,750 72,250	82,500 83,000	24.2 27.4	58.3 62.0	1/2 Cup 1/3 Cup	.110	.37	.36	.50	.57
1/8 x 14"	" 2113	110	24.0	74,000 62,000	86,000 94,000	21.9 21.9	60.0 59.5	1/2 Cup 1/2 Cup	.134	.44	.48	1.00	.57
5/32 x 14"	" 2113	150	22.0	72,500 73,000	88,500 89,500	22.7 23.5	58.3 60.6	Full Cup Full Cup	.105	.40	.40	.97	.53
3/16 x 14"	" 2113	180	22.5	75,500 75,500	90,250 90,000	24.2 23.5	61.5 60.6	Full Cup 1/2 Cup	.093	.40	.37	1.01	.52
1/8 x 14"	" 4113	110	21.5	86,000 86,000	100,000 100,000	18.8 18.8	53.8 56.4	1/2 Cup 1/2 Cup	.130	.44	.48	2.31	.51
5/32 x 14"	" 4113	150	23.0	75,000 77,500	92,000 94,500	21.9 20.3	57.5 61.6	Irregular 1/2 Cup, g.h.	.128	.44	.44	2.32	.56
3/16 x 14"	" 4113	180	24.0	78,500 78,000	96,000 95,000	18.8 20.3	53.2 54.3	1/2 Cup, g.h. 1/2 Cup, g.h.	.121	.43	.44	2.24	.48
1/8 x 14"	" 4213	110	20.0	72,000 82,000	100,000 102,000	20.3 20.3	55.4 59.5	1/2 Cup 1/2 Cup	.137	.43	.46	2.20	.96
5/32 x 14"	" 4213	150	25.0	86,500 85,000	101,500 100,000	17.2 17.2	50.3 51.1	1/2 Cup 1/2 Cup	.127	.35	.35	2.15	.90
3/16 x 14"	" 4213	180	24.0	84,500 84,000	100,000 99,500	17.2 19.6	47.5 56.0	1/2 Cup, g.h. 1/2 Cup, g.h.	.151	.35	.38	2.23	.93
1/8 x 14"	" 1110	100	26.0	56,000 56,000	72,000 72,000	28.1 28.1	68.5 70.2	1/2 Cup 1/2 Cup	.092	.40	.16	.52	.58
5/32 x 14"	" 1110	135	25.0	54,500 53,500	67,500 67,000	31.3 31.3	70.1 70.2	1/2 Cup 1/2 Cup	.082	.31	.17	.61	.58
3/16 x 14"	" 1110	175	25.5	49,000 45,500	64,000 63,000	34.4 32.1	69.9 70.6	1/2 Cup, g.h. 1/2 Cup	.086	.36	.15	.56	.46
1/8 x 14"	" 2110	100	26.0	62,000 64,000	82,000 82,000	26.6 23.4	64.8 63.4	1/2 Cup Full Cup	.112	.37	.19	1.13	.58
5/32 x 14"	" 2110	135	25.0	58,000 58,000	69,500 72,000	28.9 28.9	70.9 67.3	1/2 Cup 1/2 Cup	.089	.39	.17	1.09	.54
3/16 x 14"	" 2110	175	26.0	54,000 59,500	67,250 67,250	29.7 28.9	63.3 71.0	1/2 Cup, g.h. 1/2 Cup	.069	.37	.14	1.03	.52
1/8 x 14"	" 4110	100	27.0	70,000 64,000	84,000 80,000	25.0 25.0	65.3 66.8	1/2 Cup 1/2 Cup	.104	.41	.19	2.19	.50
5/32 x 14"	" 4110	135	25.5	62,500 64,000	80,500 82,000	25.8 22.7	67.0 66.3	Full Cup 1/2 Cup	.085	.44	.18	2.26	.48
3/16 x 14"	" 4110	175	29.0	60,500 59,000	79,500 78,500	24.2 22.7	65.4 64.4	Full Cup 1/2 Cup	.071	.43	.17	2.19	.49
1/8 x 14"	" 4210	100	26.5	74,000 74,000	94,000 92,000	23.4 23.4	63.4 64.8	1/2 Cup 1/2 Cup	.118	.41	.17	2.06	.87
5/32 x 14"	" 4210	135	26.0	64,500 67,500	82,500 84,500	22.7 25.8	66.8 58.8	Full Cup 1/2 Cup	.100	.40	.17	2.23	.99
3/16 x 14"	" 4210	175	26.0	66,500 66,000	84,500 84,500	22.7 25.0	60.8 64.2	2/3 Cup 1/2 Cup, g.h.	.085	.43	.18	2.16	.93

Table 3A

Electrode	Stress Relief	Preheat and Interpass Temp., ° F.	Yield, Psi.	Ultimate, Psi.	Elong. in 2 In., %	Reduct. of Area, %
3/16-In. Type 4210	1150° F. 1 hr.	212	88,000	112,500	16.4	51.9
			97,000	114,000	16.4	51.4
3/16-In. Type 4210	1300° F. 2 hr.	500	66,500	84,500	22.7	60.8
			66,000	84,500	25.0	64.2

addition to supplying a range of alloy content for the stabilization of carbides, the variety of analyses has a great effect on the physical properties of the deposited weld metal.

Physical Properties

Properties of typical weldable chromium-molybdenum alloy steels are given in Table 1. The chromium and molybdenum contents may be varied over a considerably wider range and this is being done in the industry. The physical properties are proportionately varied.

It has been stated that a wide range of physical properties is available in the deposited weld metal. These are influenced principally by the chemical analysis of the deposited metal, the similarity with and extent of dilution by the parent metal, and the heat-treating cycle.

Table 2 lists the physical properties of all-weld metal tensile specimens prepared using 3/16-in. diameter electrodes only in accordance with A.W.S.-A.S.T.M. Tentative Specifications for Iron & Steel Arc Welding Electrodes, Serial Designation A233–45T dated 1945. To meet this specification the specimens were stress relieved at 1150° F. for one hour with heating and cooling rates set at 325° F. per hour.

The effect of heat treatment is well shown by comparing the physical properties in Table 2 with those for the same electrodes in Table 3 where stress relief was performed at 1300° F. for two hours with heating and cooling rates set at 325° F. per hour. In this case a preheat and interpass temperature of 500° F. was used throughout. The plate temperature was determined by a surface pyrometer.

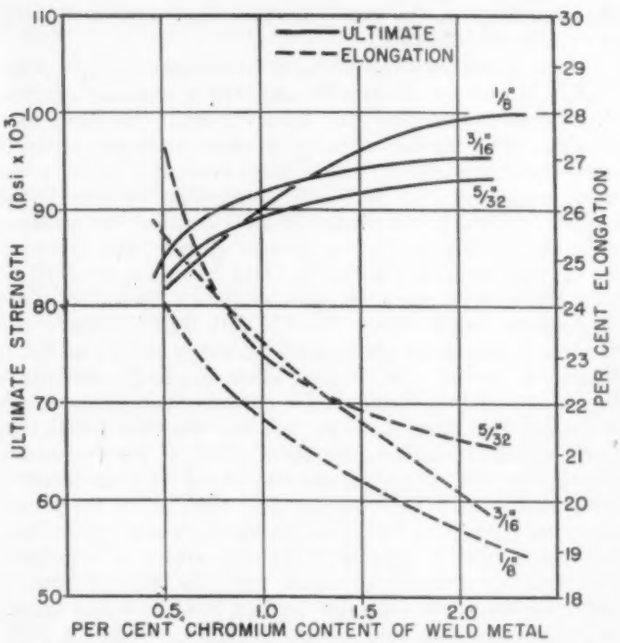

Fig. 6—Relation Between Physical Properties and Chromium Content of Weld Metal Deposited by Chrome-Moly Electrodes with A.W.S.-A.S.T.M. XX13 Base Coating. Molybdenum Content Held at 0.5%. (Specimens Stress Relieved at 1300° F. for 2 Hours)

Fig. 7—Fractured All-Weld Metal Tensile Specimen Welded with Type 1113 in the $^{5}/_{32}$-, $^{3}/_{16}$-, and $^{1}/_{8}$-In. Diameters, Respectively

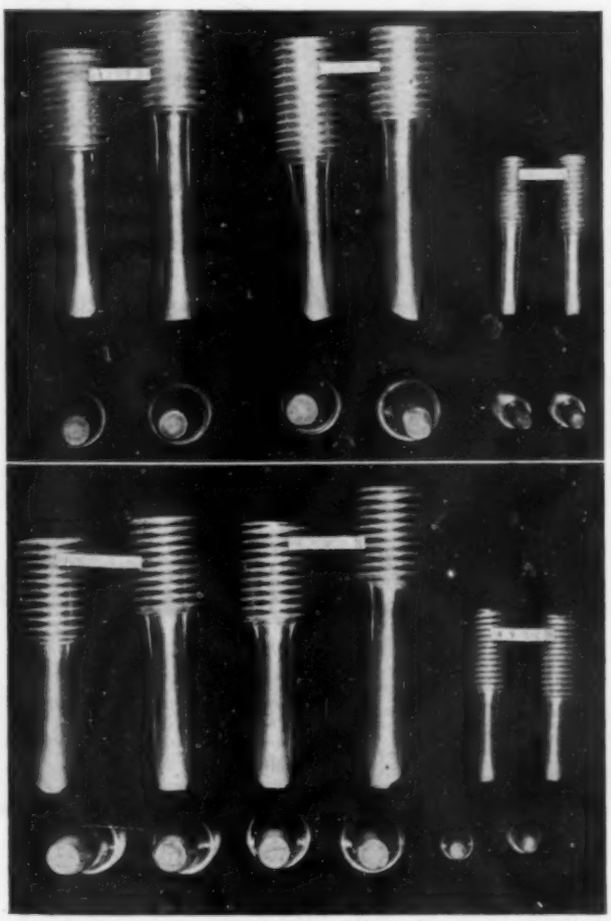

Fig. 8—Fractured All-Weld Metal Tensile Specimens Welded with Type 2113 in the $^{5}/_{32}$-, $^{3}/_{16}$-, and $^{1}/_{8}$-In Diameters, Respectively

To illustrate the effect of heat treatment a typical example can be taken from Tables 2 and 3. The same electrodes are employed in each case but the contrast in tensile properties is clearly shown. (Table 3A)

Any operation which has so great an effect on the results must be carefully controlled. All tensile specimens reported herein were stress relieved in an electric

Fig. 9—Fractured All-Weld Metal Tensile Specimens Welded with Type 4213 in the $^{5}/_{32}$-, $^{3}/_{16}$-, and $^{1}/_{8}$-In Diameters, Respectively

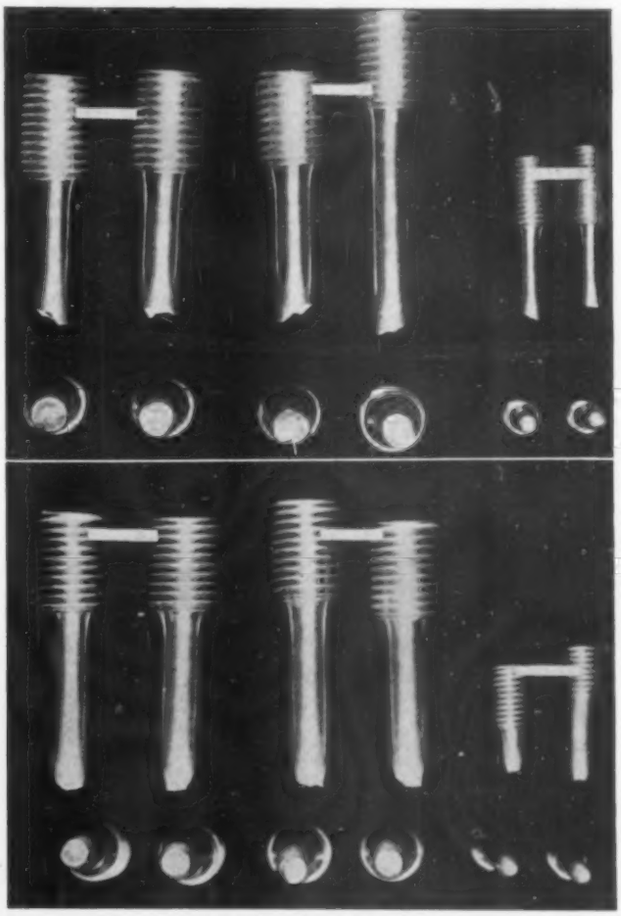

Fig. 10—Fractured All-Weld Metal Tensile Specimens Welded with Type 1110 in the $^{5}/_{32}$-, $^{3}/_{16}$-, and $^{1}/_{8}$-In Diameters, Respectively

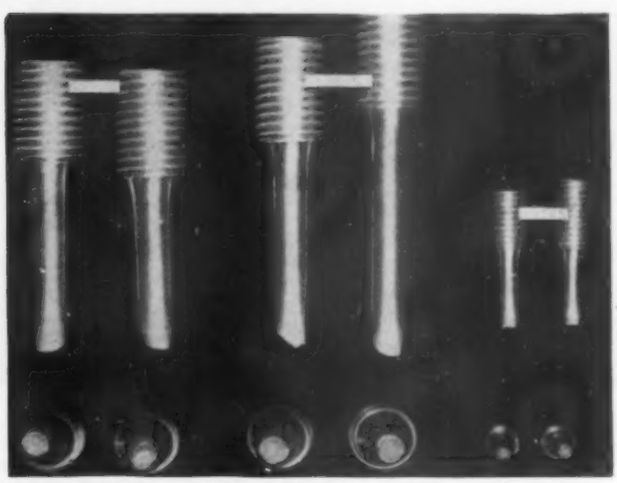

Fig. 11—Fractured All-Weld Metal Tensile Specimens Welded with Type 2110 in the $^{5}/_{32}$-, $^{3}/_{16}$-, and $^{1}/_{8}$-In Diameters, Respectively

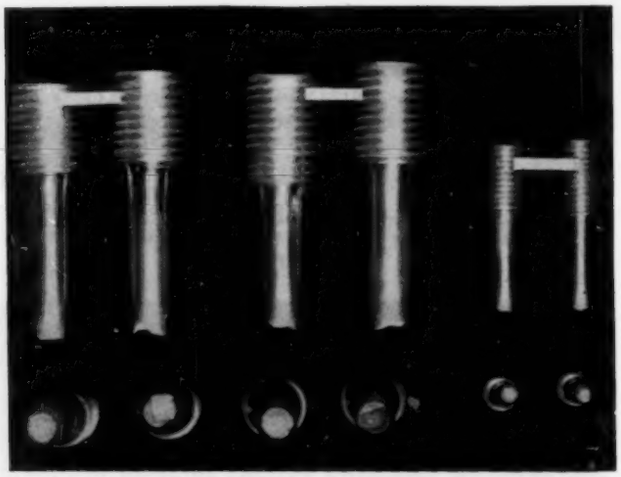

Fig 12—Fractured All-Weld Metal Tensile Specimens Welded with Type 4210 in the $^5/_{32}$", $^3/_{16}$", and $^1/_8$"-In Diameters, Respectively

furnace controlled by a Leeds & Northrup Micromax automatic program controller. The equipment used is illustrated in Fig. 3. Each stress-relieving cycle is recorded on a chart. Figure 4 gives a typical chart for stress relief at 1150° F. for one hour. The close control of the heating and cooling gradients and the accurate holding of the specimens at the prescribed time and temperature are important requirements. Note the sharp breaks in the curve at the start and end of the period at temperature.

Table 3 also lists the physical properties of the $^1/_8$- and $^5/_{32}$-in. diameter electrodes and the chemical analyses of all-weld metal deposits obtained with the same electrodes. The variation in yield and ultimate strength with the composition of the metal is greater in the lower alloy contents and falls off somewhat in the higher ranges. For a given change in alloy content the ultimate strength is affected to a greater degree, for example, in varying from 0.5 to 1.0% than from 1.5 to 2.0% of alloyed element even though a constant change of 0.5% is made in each case. The XX10 base displays this tendency in a more pronounced manner than the XX13 base. However, the higher alloy contents provide a larger amount of elements for carbide stabilization. In addition, the curves shown are for one stress-relieving cycle which holds the material at 1300° F. for two hours. Increasing the temperature at which the material is held during heat treating permits the higher alloy contents to have greater effect on the physical properties. Figures 5 and 6 also indicate the effect of electrode diameter on tensile strength and ductility. Smaller diameter electrodes usually deposit weld metal of higher ultimate strength and lower ductility. This is principally a result of the lower penetration of the small diameters which provides less heat treating of the joint as each successive pass is put in, although there are a number of other contributing factors.

Characteristic differences in deposit analyses are found

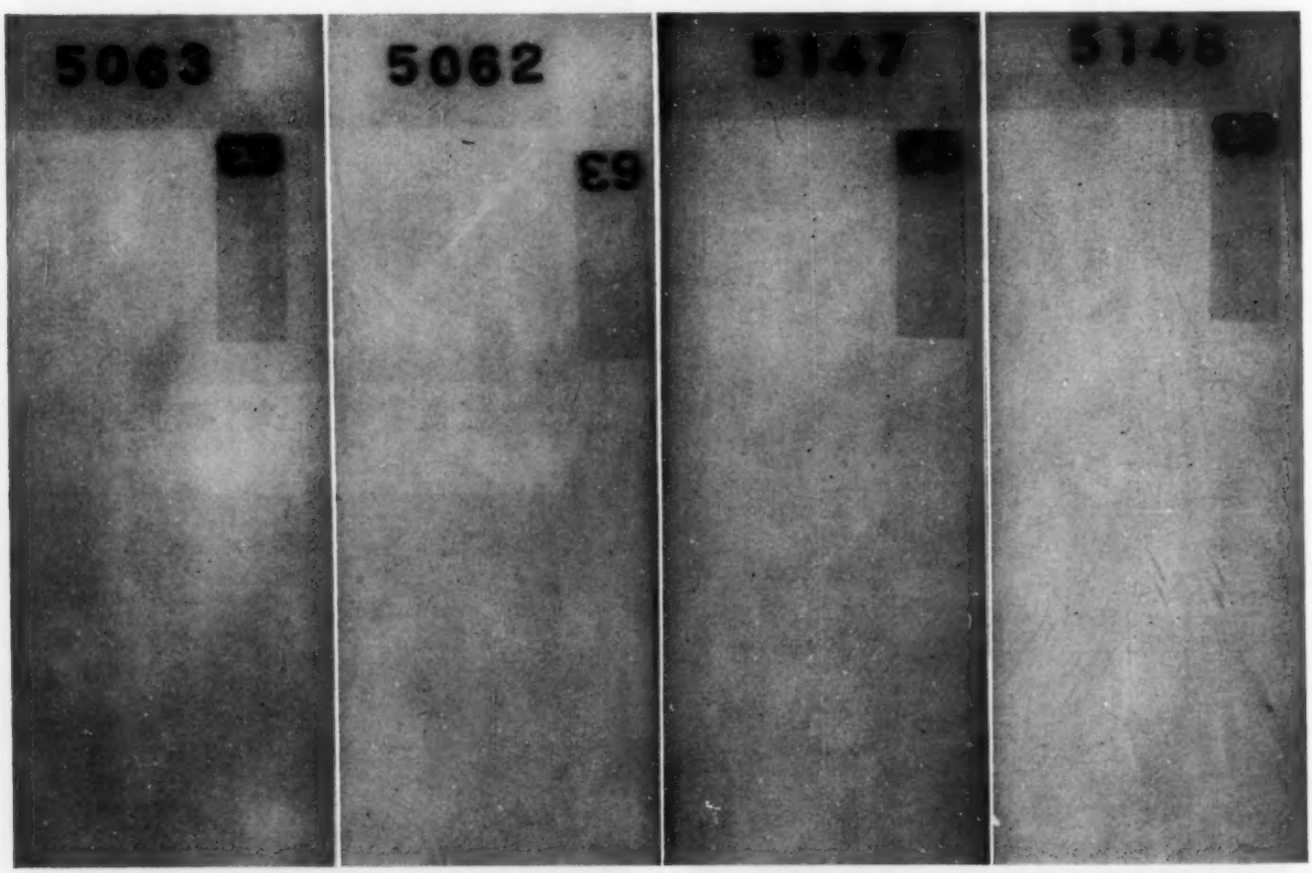

Fig. 13 Fig. 14 Fig. 15 Fig. 16

Fig 13—Exograph of Butt Joint Welded with $^3/_{16}$-In. Type 4210
Fig 14—Exograph of Butt Joint Welded with $^3/_{16}$-In. Type 4213
Fig 15—Exograph of Butt Joint Welded with $^3/_{16}$-In. Type 1110
Fig 16—Exograph of Butt Joint Welded with $^3/_{16}$-In. Type 1113

between the base coatings in Table 3. The XX13 base is slightly higher in carbon and manganese content. A more significant difference rests in the silicon content where the XX13 base runs 0.35 to 0.50% and the XX10 base 0.15–0.20% silicon. Part of the reason for the variation in tensile properties of the two bases arises from differences in the carbon, manganese and silicon content of the deposit.

Figures 7, 8 and 9 show the type of fracture obtained in the all-weld metal tensile specimens of the XX13 base. Figures 10, 11 and 12 are similar specimens from welds made with the XX10 base. The $^1/_8$-, $^5/_{32}$- and $^3/_{16}$-in. diameters are represented at three levels of alloy contents in each case. The physical results obtained on the specimens are those given in Table 3 under the corresponding electrode type. The "necking down" or rapid reduction in section of the specimen approaching the fracture demonstrates the good ductility of the steel while the normal cup formations which the fractures show and the absence of tears along the body of the specimens attest to the high quality of the weld.

As might be expected, these electrodes, especially with the higher alloy additions, require preheating and postheating of the joint to be welded, or cracked welds will result. Preheats higher than 600° F. are rarely necessary and lower preheats can often be used.

Satisfactory freedom from X-ray porosity has been shown. Figures 13, 14, 15 and 16 are X-ray reproductions of butt joints in $^3/_4$-in. molybdenum steel plate welded in the flat position with the $^3/_{16}$-in. diameter of both base coatings with the highest and lowest alloy content reported herein. The $^3/_{16}$-in. diameter was chosen for reproduction here as X-ray soundness decreases with increasing diameter so that this electrode size represents the least favorable condition. The split weave technique is used in preference to the full weave as it produces sounder weld metal. In full weave each successive pass in the weld is deposited across the full width of the gap between the sides of the joint at that point, requiring a proportionately wide weave except at the root of the joint. The split weave technique requires the deposition of each succeeding pass in two or more beads which overlap each other slightly. Consequently, the width of weave is considerably reduced and sound weld metal results. The four exographs were selected as being representative of the extremes in performance from a large number which have been made. The two XX13 base exographs, Figs. 14 and 16, are completely free of porosity. Figure 13 on $^3/_{16}$-in. Type 4210 shows a low level of porosity while Fig. 15 of a joint welded with $^3/_{16}$-in. Type 1110 is reproduced here to show a high level of porosity. This result can be improved by using a narrower weave and by not oscillating the electrode as rapidly while weaving during welding. With proper technique, the XX10 base satisfies the normal requirements on X-ray porosity while the XX13 base is still better, giving consistently clean exographs when normal care is used.

In general, the welding operation for quality piping using chromium-molybdenum steels is subject to the procedures that have already been developed for work of this caliber. The basic approach must include three important factors:

1. Correct weld design.
2. Evolution of a suitable welding technique.
3. Proper qualification of the welding procedure and welding operators.

Although no attempt will be made to discuss these factors here, they must be carefully evaluated in piping applications.

Summary

Two lines of electrodes for the welding of chromium-molybdenum steels are presented with all-position welding characteristics depositing metal of X-ray quality with ultimate strengths from 65,000 to 100,000 psi. and elongations from 17 to 35% when stress relieved at 1300° F. for two hours. Variations in the heat-treating cycle expand the range of physical properties still further.

The weld metal has a controllable composition which can be conveniently varied in 0.5% increments of both chromium and molybdenum.

Primarily intended for power piping and similar high-quality work, important applications for the electrodes can be found over a wide variety of low-alloy steel fabrication.

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So You're Starting Your Own Welding Shop

Check Your Facts Before You Open Your Business

By H. Ullmer*

IT is estimated that many returning veterans and civilians who gained welding skill in war industries will set up their own welding business. Under the GI Bill of Rights, a veteran can obtain Government-backed financing provided he can satisfy certain requirements. First, he must be qualified by experience and ability to manage a business; second, he must find a lending agency—bank, insurance company, or individual—to make him a loan at an interest rate of no more than 4%. He can then apply to the Veterans' Administration for a Government guaranty for a certain percentage of the loan, not to exceed a fixed maximum.

Rewards and Risks

A small successful business can earn more for its owner than he could make in a large or medium-sized business except in a top executive position. Some of the profit must be put back into the business if it is to grow; a percentage of the profit must also be used as a reserve fund. Big money returns come to comparatively few.

There are other rewards that mean more to many men than a higher income. The owner of a business is his own boss, forms his own policies, and can put his own ideas into action. He has a high standing in the community and is recognized as a man with initiative and ability. Independence of spirit and freedom from fear of being fired bring him a deeper sense of security than is possible on a job.

On the other side of the ledger there are plenty of headaches to consider. The owner of a business often works longer hours than his employees. Unless he has a partner or trained assistants, the owner is tied down to his business, unable to take a vacation for more than one or two days at a time. He must meet his payroll, pay his other bills, get business, collect accounts, attend to the many details involved in operating a business. If the business just "gets by," many owners make less than they could earn by working for others. Yet they have all the responsibility of ownership. If the business fails, the owner will lose all or part of his capital. Although more new businesses fail than succeed, many of those in danger of failure quit while they still show a profit. Others sell the business and suffer little or no financial loss.

A successful business man is a "self-starter," that is he has initiative. Industry and self-confidence are probably the next important character traits. Do you possess these qualities and also perseverance, tact, enthusiasm, ability to organize work, handle details and assume responsibility? Many men succeed because they have some of these traits highly developed. Very few have all of them in a high degree.

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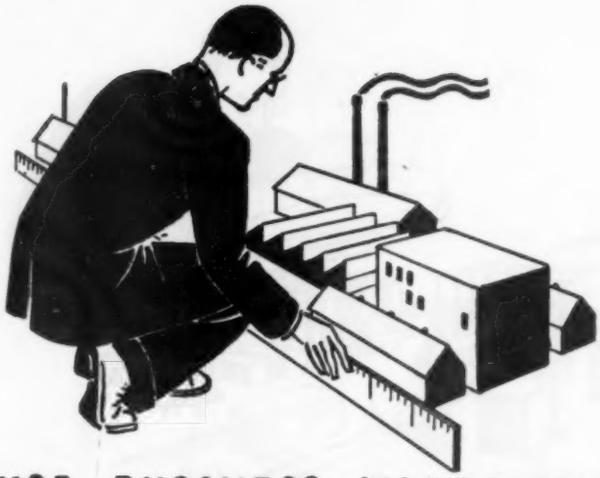
Three Business "Musts"

There are three essentials for success in any business: (1) an adequate market, (2) sufficient capital and (3) business ability or "know-how." Check and recheck your plans and make sure before you open your doors that you have these essentials. It is only common sense to analyze your prospects for success before risking a penny.

Use Business Yardsticks

You can apply basic measures of business possibilities in making your analysis. The U. S. Department of Commerce estimates that a shop cannot expect to prosper when serving an area with less than 20,000 population. The income level and occupation of the population must also be considered. The number of motor vehicles registered in an area in proportion to the population is an indication of the general level of prosperity. If a number of plants making a variety of products furnish employment, a shutdown of one factory will not curtail all business activity. Such a community is also likely to fare better in a depression than an area that depends mainly on a few enterprises.

To be really useful, your analysis must be thorough and it must be as exact as possible. Many agencies are ready to help you and have already prepared facts and figures that will be valuable. The local Chambers of Commerce,



USE BUSINESS YARDSTICKS

Better Business Bureaus, banks and leading businessmen welcome the opportunity of aiding the returning serviceman. Your Government maintains a special service organization to help you, the Bureau of Foreign and Domestic Commerce. Operating under the Department of Commerce, this Bureau provides a storehouse of business information. It gathers facts, interprets them and makes them available in printed form. You will find these publications very useful. For example, the Basic Data Sheets on counties and independent cities will give you in a ready-to-use form many of the facts you need to know about the area you expect to serve.

The Bureau of Foreign and Domestic Commerce maintains 26 field offices located in large cities throughout the country. Here you can obtain expert advice on any business question in a personal interview with a specialist in your field. The many services of the Bureau are set up so that you can use them easily. Learn about them and make free use of them. Your Government maintains them for your benefit.

Estimate Your Market

A poor market is a handicap that you cannot overcome. Therefore an analysis of the community where you plan to locate is of first importance. How many and what different kinds of industrial plants and factories are already established, and how much welding work do they have? How much work can you expect to develop at these plants or do they have their own welding departments? Is the community a center for a farming area that can be expected to provide repair jobs on farm machinery? How much additional work can be expected from other sources—trucking concerns, bus companies, building contractors and home owners? Is there a possibility of obtaining repair work from local highway or other departments? How much of a market is there for special items you might manufacture by welding?

Consider Your Competition

From a combination of all available sources of information, you can get a factual picture of the community and of the competitive situation. It is important to know as much as possible about the existing welding shops in the community before you decide to establish your shop. If the field is already crowded, you may prefer to consider another location. This decision should not be made, however, until you analyze closely the quality of work, equipment and general standing of the other shops. There may be a need for some type of service—such as hard facing or flame hardening—that the other welding shops are not equipped to turn out profitably.

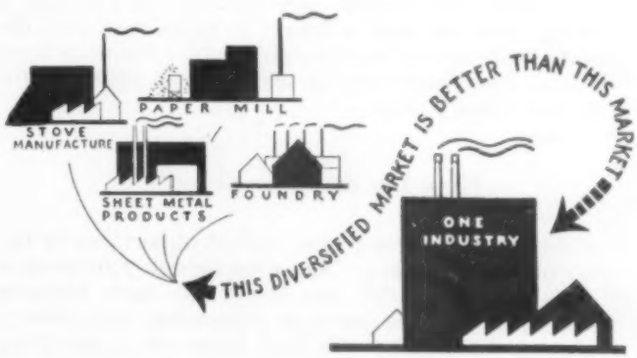
In industrial areas where there is a large amount of profitable business, there will naturally be considerable competition. You cannot judge your chances of success by a slide rule. However, after considering all factors, you may have enough confidence in your work and your business-getting and managerial ability to establish your shop. Even in a crowded area you may find enough demand for a particular kind of work to specialize in it. For example, welding operators in several parts of the country have become so expert in hard facing that they have plenty of work, even though there are many welding shops in the same area.

Size up the attitude of the town where you plan to locate. Some towns have a hostile attitude toward new businesses. The leading citizens control everything, resent strangers and try to block the introduction of new businesses. Avoid such communities. Locate your business in a friendly town, where you can anticipate a welcome for your business and have at least an even chance for success.

Choose a Desirable Location

A good location is as essential for your shop as it is for the retail store. Remember that a roomy shop in a convenient location is more useful for your type of business than an imposing front. Weigh the advantages and disadvantages of the buildings available in sections where zoning restrictions will not affect the location of a welding shop. Consider locations on side streets open to heavy trucking, where your suppliers' trucks can deliver at your door. Rent is a major item of overhead, a factor that will enter into every job you bid for. Do not pay too much. On the other hand, some low-rent sections have disadvantages of appearance and reputation that make them unsuitable.

When you have narrowed down your choice, compare the buildings carefully. Lack of parking space will keep customers away and unpaved streets may be inaccessible in the winter. Doors large enough to admit trucks will permit unloading work right in the shop and will save the time and labor required to haul it inside. Make sure that gas, electricity and water will be available in the amounts you need, and check the rates. If any alterations must be made, get an estimate beforehand. The difference in alteration costs may be the deciding factor in your final selection.



$$$ Know Your Capital Needs $$$

A full knowledge of the financial requirements before starting in business is another "must." Note that financial requirements cover both invested capital and working capital. You have doubtless set a maximum figure for your outlay. After you have picked your location and decided on the type of shop to establish, make an estimate to cover all necessary expenditures. These will include monthly rent—or the first payment if you are buying a building—down payments on equipment, insurance fees, initial advertising costs, deposits for telephone service, gas and electricity, supplies and whatever expenses you will incur before starting in business. You will have acquired by now a knowledge of local real estate values. If you know, for example, that all available business premises will require structural changes, additional wiring or other alterations, add the cost to your estimate. Try to anticipate all your expenses so that you will not be faced with unexpected drains.

It is difficult to set a minimum amount for starting a welding shop. You may be able to start with as little as $1000 or even less. Experience shows, however, that over 50% of the shops established on so narrow a margin fail within the first year. Chances are against success when the amount of capital is insufficient. If you start your business on an absolute minimum, you risk the loss of your total investment. Your working capital should provide a reserve to tide you over a period of early failure or small success. Veterans who need the guaranteed loan benefits of the GI Bill of Rights do not have to rush into business to obtain them. They have a specified number of years in which to complete their plans, build up capital and gain any additional experience they may need.

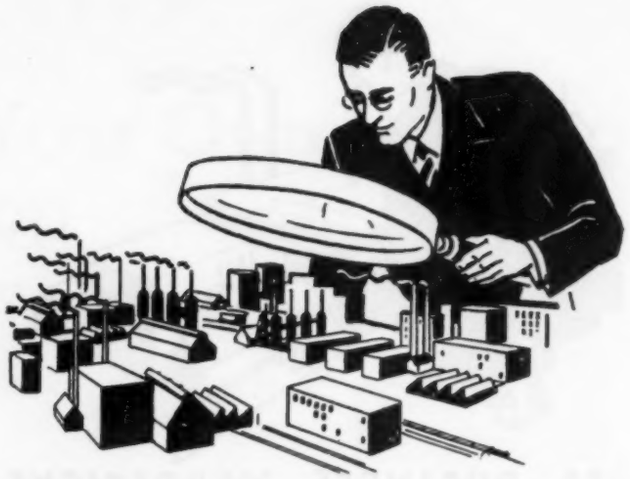
You may have the opportunity to buy an established business and acquire with it some of its customers and the goodwill of a going concern. This will save the time and effort of fitting out your shop and, if the price is right, it has its advantages. However, make a careful inventory of all equipment, check its condition and appraise its value. The difference between the asked price and the value of all the assets is the amount you will pay for the goodwill of the business. Consider its real worth to you before you close the deal.

Get Legal Advice

A competent lawyer can save you the cost of his services many times over. Consult one before you proceed very far with your plans and inform yourself on the state and city requirements. For example, the city, county or state may require a permit or license. Failure to obtain one may subject you to a penalty. If you employ workmen, you must comply with state and local factory regulations and with the Social Security programs operated by the state and federal Government. If you buy a business, you will need a lawyer to make sure that the transfer conforms to legal requirements. Estimate legal advice as a necessary expense and make an allowance for it in your initial outlay.

Have You the "Know-How"?

Ability to weld is, of course, of first importance to the owner of a welding shop. But even though your work is of the highest quality, you must also have business "know-how," that is business experience and ability. Everybody knows men who have begun on a shoestring



CONSIDER YOUR COMPETITION

and succeeded because they had enough" know-how" to overcome the handicap of insufficient capital at the start. These cases are the exception, though, and the rule of three—market, capital and business experience—is the basic rule of success.

Business "know-how" is a big subject. Many books have been written about what it is and how to develop it. It depends more or less on intangible traits, some of which were briefly mentioned in the beginning of this article. You can judge your mechanical ability by comparing the speed and quality of your work against the work of other mechanics. Compare yourself with men who have had some success in business to judge whether you can match them in the qualities that make for business success.

It may be helpful to draw up a listing of the qualities considered important for success in business. Such a list will include initiative, perseverance, industry, personality, tact, sincerity, enthusiasm, leadership, ability to organize work and handle details, and willingness to assume responsibility. Rate yourself on each of these qualities. Do not give yourself a rating for what you think you could do, but for what you actually have done. In other words, stick to facts. If, for example, you can think of three opportunities you failed to take advantage of during the past year, you should not grade yourself very highly in aggressiveness.

Ask several friends who know you well to rate you, too, and then take an average. Do not take offense if you receive a lower rating from your friends than you think you deserve. Remember that it is very difficult to judge yourself. You may actually have qualities that you think you have but particular occasions may not have arisen to bring them to the attention of your friends. An excellent way to arrive at a fair estimate of your character traits is to ask the help of a vocational counselor or a personnel manager from a large company. They are trained in judging these qualities from an impersonal viewpoint. Either one can probably give you advice based on wide experience in daily work.

The field of economic and business research offers some help in testing for these intangible qualities. To measure your initiative, you might ask whether you ever started anything, a social activity, club or a new way of doing something? Do you take the lead in planning any group activity? Do you start things at work without being told to do so?

Initiative is an essential quality, but some "good starters" are "bad finishers." So check upon your perseverance and industry. They are "must" qualities for

THIS IS A HEALTHY COMBINATION FOR SUCCESS

the owner of a successful business. Do you quit when the job gets tough? How many things have you started and left unfinished? Have you the staying qualities that keep you in the race when things do not run smoothly? You must expect to encounter difficulties in your business and you must persevere in carrying out ideas you believe in. Along with this you need to possess industry, or just plain willingness to work. The owner of a business has to work longer and harder than an average employee. He is tied down to his business, has to give it his constant attention and accept all the responsibility.

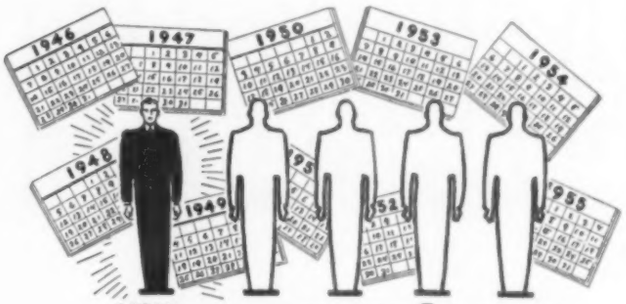
Your personality and ability to win friends is important. Do you naturally like to be with people or do you prefer to be alone? Joining clubs and associations is part of the business game. If you employ people your personality counts, too, in winning their cooperation. You must meet your customers and prospects, sell them on your services. People prefer to do business with people whom they like and enjoy meeting. Your tact, sincerity and enthusiasm are qualities that influence people and help in your business relations as well as socially. Qualities of leadership inspire others. Men who are good leaders usually have good business ability.

You may notice that intelligence has not yet been mentioned as an essential quality. Business management requires intelligence of course. However, some men of only average intelligence have a gift for putting over a business and making it grow. Some studies indicate that owners or executives of larger businesses are highly intelligent. However, those with the highest intelligence are little, if any, more successful than those with a somewhat lower intelligence rating. Business success appears to depend to a greater extent on certain traits of character than on general intelligence.

Business Management

Business management falls naturally into three main divisions: (1) equipping and organizing your shop and establishing basic operating practices; (2) maintaining an adequate system of bookkeeping; and (3) merchandising your services and providing for future growth. Your success depends on how well you apply your "know-how" to these three phases of your business. If you have a partner you can divide the work of management. If you have a one-man shop, everything depends on your own enterprise. Statistics show that about 30% of small businesses fail in the first year and 14% more fail in the second year. At the end of 10 years, only one out of five is still in business. You can be that one man in five if you prepare carefully and follow up with the proper action.

Good equipment and sound organization are vital to the efficiency, economy and coordination of your business. An article, "This Well-Planned Welding Shop Pays Dividends," in the May 1941 issue of *Oxy-Acetylene Tips* has several interior views and a general layout of a small shop.



YOU CAN BE THE ONE MAN IN 5 TO SUCCEED AT THE END OF 10 YEARS IN BUSINESS

Bookkeeping is close to the top of the list of the fundamental things you should know. Not that you need to be an experienced bookkeeper, but you should know how much it costs you to open your doors each morning. Two articles from previous issues of *Oxy-Acetylene Tips* will help with this part of your work. "Cost Finding for the Welding Shop" appeared in the August 1940 issue and "A Simplified Bookkeeping System" was printed in the March 1941 *Oxy-Acetylene Tips*.

You may be an expert welding operator, but when you open your own shop, something more is needed. The world no longer beats a path to the manufacturer of a better mousetrap, unless he tells the world about it. Competition in the postwar years will be tough and you must have a merchandising program to attract customers.

INSPECTION HANDBOOK

FOR

MANUAL METAL-ARC WELDING

EDITORIAL NOTE. The AMERICAN WELDING SOCIETY has just issued a book of 156 pages on the above subject. The book has been prepared by the American Welding Society's Army Ordnance Advisory Committee as an aid to the inspector in the performance of his duties and serves as a reliable source of basic information. The first nine Sections deal with requirements and duties of a welding inspector, definitions, symbols, procedure specifications, qualification of operators and heat-treating operations. Sections 10 and 11 are reproduced herewith. Copies of the book may be obtained from the AMERICAN WELDING SOCIETY, 33 West 39th Street, New York 18, N. Y., at $1.50 per copy.

SECTION X—WELDMENT DEFECTS

1001. General

Weldment defects are of three general classes: first, those that are associated with drawing or specification requirements; second, those associated with structural discontinuities in the weld itself; and third, those associated with properties of the weld metal or of the welded joint. These classes of defects may be further subdivided as follows:

Dimensional defects

(*a*) Warpage
(*b*) Incorrect joint preparation
(*c*) Incorrect weld size
(*d*) Incorrect weld profile

Structural discontinuities in weld

(*a*) Porosity
(*b*) Nonmetallic inclusions
(*c*) Imperfect fusion
(*d*) Incomplete penetration
(*e*) Undercutting
(*f*) Cracking
(*g*) Surface defects

Defective properties (weld metal and joint)

(*a*) Mechanical properties
(*b*) Chemical properties

Since it is impossible to devise rules which will enable an inspector to identify all of the factors likely to cause defects in welds, this discussion will attempt to describe only a few of them briefly. A thorough knowledge of the limitations of a given welding process, along with an understanding of the conditions which are likely to promote formation of defects, will better fit the inspector to judge the probability of obtaining welds which are satisfactory for a particular service.

This discussion applies specifically to the metal-arc welding process. However, a knowledge of defects encountered in welds deposited by this process may also be useful to the inspector should he become involved in the inspection of welds made with other welding processes. Three additional limitations are placed on the scope of this discussion except as otherwise specifically noted:

Only those materials will be considered which are known to readily permit the production of a satisfactory welded joint.

A joint design will be considered which, under test conditions, will produce a satisfactory welded joint.

An electrode will be considered which is capable of producing sound deposits of proper contour properly fused to the base metal in the required position of welding.

1002. Dimensional Defects

The production of satisfactory weldments depends upon, among other things, the maintenance of specified dimensions whether it be the size and shape of welds or finished dimensions of an assembly. Requirements of this nature will be found in the drawings and specifications. Departure from the requirements in any respect should be regarded as a dimensional defect which must be corrected before final acceptance of the weldment unless a waiver is obtained. Each type of defect of this nature is discussed in the paragraphs which follow.

1003. Warpage

The welding operation involves the application of heat and the fusion of metal in localized sections in the weldment. Stresses of high magnitude may be set up due to thermal expansions and contractions, which persist in the weldment after the structure has cooled. Such stresses tend to cause distortion of the structure. (See Fig. 10.) By the use of rigid fixtures and by a judicious selection of welding sequence, positive and negative stresses may be introduced that tend to counteract each other so that by such methods warpage may be minimized. Peening also has been used to some extent as a preventive measure to keep distortion to a minimum.

The correction of this type of defect in a completed weldment usually necessitates following one or more of the procedures set forth below.

(*a*) Straightening operation with or without the application of heat.

(*b*) Removal of the weld or welds causing the trouble, followed by subsequent rewelding.
(*c*) Either removing metal or adding weld metal where possible.

The use of corrective measures usually depends upon the specification involved or the establishment of an agreement between the fabricator and the inspector.

1004. Incorrect Joint Preparation

Established welding practice requires proper joint dimensions for each type of joint consistent with the thickness of the plates being welded. Departure from these requirements may result in a greatly increased tendency to produce many of the welding defects listed as structural discontinuities in the weld. Therefore it is important that the joint preparation be the same as shown in the applicable drawings within specified limits.

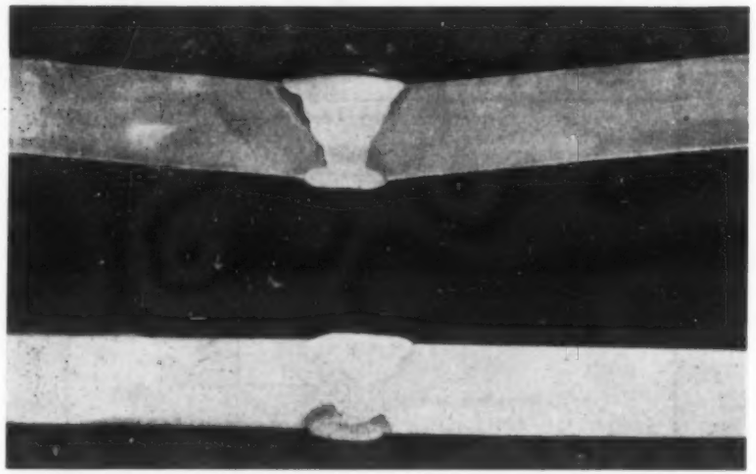


Fig. 10—Warpage

Top view shows angular distortion. Bottom view shows correct alignment obtained by use of proper control methods.

1005. Weld Size

The size of a fillet weld is expressed as the length of the shortest leg of the triangular cross section. The size of a groove weld is the depth of the groove except that where fusion materially exceeds the groove depth, the size of the weld is the depth of the groove plus the depth of fusion. Weld deficiencies due to insufficient or excessive size may be detected by visual examination or by means of a suitable weld gage.

1006. Weld Profile

The profile of a finished weld may have considerable effect upon its performance under load, whereas the profile of a single pass or layer of a multi-pass weld may have a considerable effect upon the tendency to produce such defects as lack of fusion or slag inclusion when subsequent layers are applied. Requirements concerning defects of this nature in finished welds are usually included in the specifications and drawings involved. Nonconformity with such requirements constitutes a weld defect. Figure 11 illustrates various types of acceptable and defective weld profiles.

Overlap is usually associated with fillet welding. The term describes a condition wherein a protrusion of weld metal exists at the toe of a weld beyond the limits of fusion. Figure 12 illustrates this condition. This condition tends to produce notches which are obviously harmful due to the resultant concentration of stress under load. In addition it should be considered defective welding in that the effective size of fillet is reduced. Overlap is usually caused by the use of either incorrect welding technique or incorrect electrical conditions. Overlap also can occur in certain types of groove welds although in this case it would normally be referred to as lack of fusion

Excess Convexity, like overlap, tends to produce notches. These notches are harmful in the case of a fillet weld due to the resultant concentration of stress under load. They are also harmful in the case of an intermediate pass in a multi-layer groove weld because lack of fusion or slag inclusions may occur unless corrected by chipping, grinding or oxygen grooving before depositing subsequent layers. This defect is usually due to either the use of insufficient current or improper welding technique. See Fig. 11.

Excess Concavity is usually associated with fillet welds. The actual strength of such welds is considerably less than that of standard size fillet welds since the throat is less than normal as measured by the length of leg. This condition tends to occur primarily in flat position fillet welding and is usually caused by the use of excessive welding currents or arc lengths. The only exception to this is that of welding from the top down when making a fillet weld in the vertical position. Whereas in the flat position a cure can be effected by reducing welding current, there is no cure in the vertical position except to insist that regardless of the size of fillet as measured by the leg dimensions the throat of the fillet should be equal to that of the standard fillet required.

Excess Weld Reinforcement is associated with groove welds and is considered undesirable since it tends to stiffen the section at that point as well as establish notches, thereby affecting the stress distribution when a load is applied. This condition may result from improper welding technique or insufficient welding current. See Fig. 11.

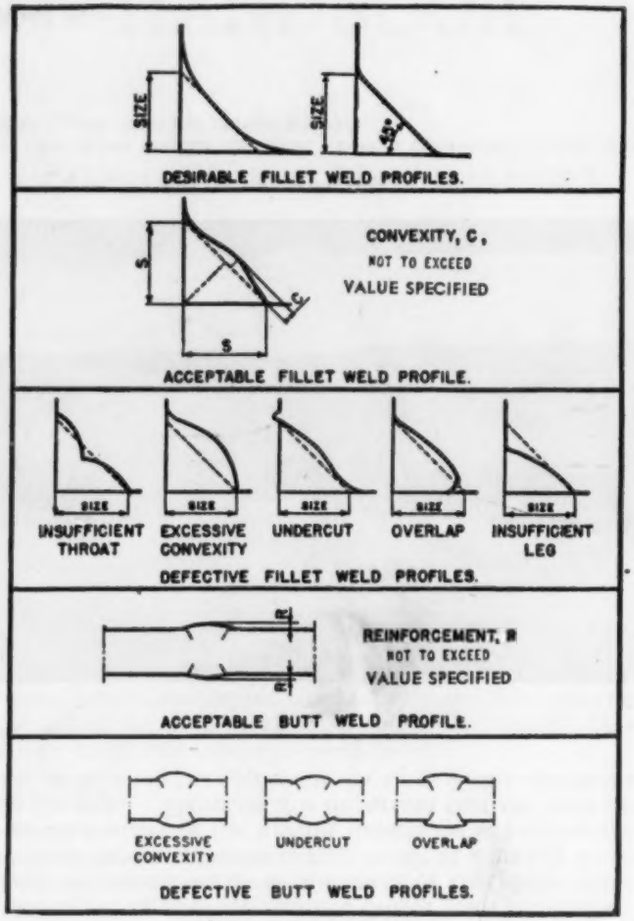


Fig. 11—Weld Profiles

Illustrating acceptable and defective weld profiles.

1007. Structural Discontinuities

In producing metal-arc welds a certain class of defects is encountered which have to do with discontinuities within the weld such as porosity, cracks, incomplete penetration, slag inclusions, etc. For want of a better term this class of defect is described as structural discontinuities. The term is not used in the sense that there is a change of metallographic structure at these points but merely means that there is either lack of weld metal or lack of fusion. Each defect of this nature is described in the paragraphs which follow.

Fig. 12—Overlap

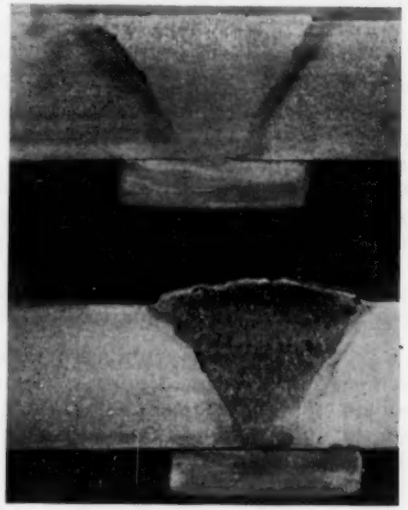


Fig. 13—Porosity

Top view shows sound weld. Bottom view shows porous weld.

1008. Porosity

The term is used to describe the globular voids free of any solid material, which are frequently found in welds. In reality they are a form of inclusion resulting from the chemical reactions taking place during welding. They differ from slag inclusions in that they contain gas rather than solids. Figure 13 illustrates this condition.

The gases forming the voids are derived from gas released by the cooling weld metal because of reduced solubility as the temperature drops; and gases formed by chemical reactions in the weld.

The formation of porosity is most readily prevented by avoiding excessive currents or excessive arc lengths. High consumption of the deoxidizing elements of the coating may take place during deposition if excessive currents and arc lengths are used, leaving insufficient quantities available to combine with the gases in the molten metal during cooling.

The distribution of porosity within a weld is of some importance. Its occurrence may be generally classified as follows:

which will be difficult to penetrate fully with the arc. Obviously, the re-

Uniformly Scattered Porosity.—This distribution is one in which the cavities are scattered more or less uniformly throughout the volume of weld metal. The individual cavities may vary from almost microscopic to 1/8 in. or more in size. However, for a given welding condition they tend to be predominantly of one size.

Group Porosity.—It often happens that cavities occur in groups or clusters separated by considerable lengths of weld metal free of porosity. Such groups are often associated with changes in welding conditions as, for example, changes in arc conditions when welding is stopped or started as in replacing an electrode.

Linear Porosity.—Linear porosity occurs in the root pass and is often regarded as a special case of incomplete penetration. It is usually defined as a condition in which three or more cavities having an average diameter of not less than 1/16 in. are distributed in a line parallel to the longitudinal axis of the weld, the average distance of closest approach of any three or more cavities being not more than 3/4 in. nor less than 1/16 in. Figures 80 to 82 illustrate examples of uniformly scattered porosity, group porosity and linear porosity as their presence appears on radiographs.

1009. Nonmetallic Inclusions

This term is used to describe the oxides and other solids which are sometimes found as elongated and globular inclusions in welds. During the deposition and subsequent solidification of weld metal, many chemical reactions occur between the metal, the arc and the electrode coating materials or with the slag produced. Some of the products of these reactions are nonmetallic compounds soluble only to a slight degree in the molten metal. Due to their lower specific gravity they tend to seek the upper surface of the molten metal unless restrained from so doing.

When welding by the metal-arc process using covered electrodes, slag may be formed and forced below the surface of the molten metal by the stirring action of the arc. Slag may also flow ahead of the arc causing the metal to be deposited over it. When slag is once present in the molten metal, from any cause, it tends to rise to the surface by virtue of its lower density. A number of factors such as high viscosity of the weld metal, rapid solidification or too low a temperature may prevent its release.

When weld metal is deposited by the metal-arc process over a sharp V-shaped recess, such as that produced by a diamond pointed tool, slag will frequently be found trapped in the weld. Under such conditions, the arc may fail to heat the bottom of the recess to a sufficiently high temperature to permit the slag to float to the surface. A similar condition exists if a sharp recess is present due to undercutting or excessive convexity of the previous bead. Slag inclusions of this type are usually elongated, and if individual inclusions, are of considerable size, or if inclusions are closely spaced the strength of the joint may be materially reduced.

Slag forced into the molten metal by the arc or formed there by chemical reactions usually appears as finely divided or globular inclusions. Inclusions of this type are likely to be a particular problem in overhead welding.

The majority of slag inclusions may be prevented by proper preparation of the groove before each bead is deposited, using care to correct contours which will be difficult to penetrate fully with the arc. Obviously, the release of slag from the molten weld metal will be aided by all factors which tend to make the metal less viscous or retard its solidification, such as preheating and high heat input per inch per unit time.

Slag in the Root Area.—In making the root pass, the electrode may be so large that the arc strikes the side of the groove instead of the root. The slag may roll down into the root opening, or it may be trapped in the metal of the root layer.

Another source of root area slag lies in imperfect grinding or chipping preparatory to making the root pass on the opposite side of the plate. The initial layer of the weld on the first side of the plate does not necessarily have to fuse through the complete depth of the root opening and even if it does will carry slag with it. In addition, the unprotected metal that comes through will be badly oxidized. The slag, oxide and irregular protusions of weld metal should be removed by chipping or grinding to clean metal before welding is started on the reverse side. If this does not remove slag completely it will remain in the penetration zone.

Fusion Zone Slag.—In removing slag preparatory to depositing subsequent passes some may remain in the corner between the weld bead and the groove face. While in most cases this slag will be melted and rise to the surface, it may not do so but may remain as an elongated inclusion in the fusion zone. This condition is illustrated in Fig. 14.

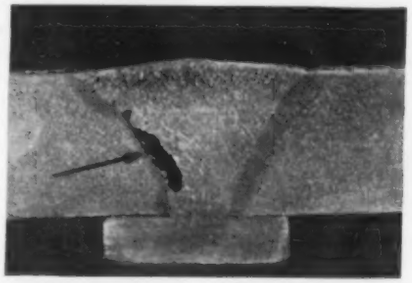


Fig. 14—Slag Inclusion

Illustrating fusion zone slag.

Scattered Slag.—Where cleaning is imperfect, there may be adhering slag in isolated areas on the surface of the last deposited layer. This slag tends to interrupt the arc and prevents fusion of the weld metal and complete remelting of the slag. The result is scattered slag inclusions distributed within the weld metal.

1010. Lack of Fusion

While this term is sometimes applied to the conditions later referred to as incomplete penetration, it is used here in a more restricted sense to describe the failure to fuse together adjacent layers of weld metal or adjacent

weld metal and base metal. This failure to obtain fusion may occur at any point in the welding groove. See Fig. 15.

Lack of fusion may be caused by: failure to raise the temperature of the base metal (or previously deposited weld metal) to the melting point or failure to dissolve, by means of proper fluxing, the oxides or other foreign material present on the surfaces to which the deposited metal must fuse.

It should not be inferred from this brief discussion that it is necessary to melt an appreciable portion of the sidewalls of the groove in order to be certain of securing proper fusion. It is only necessary to bring the surface of the base metal to the fusion temperature to obtain metallurgical continuity of the base and weld metal.

Lack of fusion is best avoided by ascertaining that the surfaces to be welded are free of injurious foreign material and by the use of welding operators who have adequately demonstrated their ability to make sound welds.

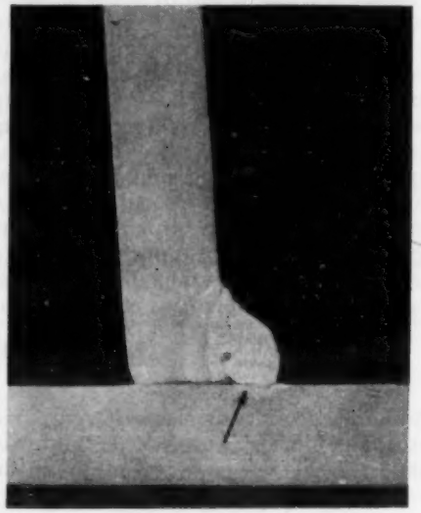


Fig. 15—Lack of Fusion

1011. Incomplete Penetration

This term is applied to describe the failure of the deposited metal and base metal to fuse integrally at the root of the weld. It may be caused by the failure of the root face of a groove weld to reach fusion temperature for its entire depth, or the failure of the weld metal to reach the root of a fillet weld leaving a void caused by bridging of the weld metal from one member to the other. Figure 16 illustrates this condition in a groove weld; Fig. 17 illustrates this condition in a fillet weld.

Although incomplete penetration may, in a few cases, be due to failure to dissolve or flux surface oxides and impurities, the heat transfer conditions existing at the joint are a more frequent source of this defect. If the areas of base metal which first reach fusion temperatures are above the root, molten metal may bridge between these areas and screen off the arc before the base metal at the root melts. In metal-arc welding, the arc will establish itself between the electrode and the closest part of the base metal. All other areas of the base metal will receive heat principally by conduction. If the portion of the base metal closest to the electrode is a considerable distance from the root, the conduction of heat may be insufficient to attain fusion temperature at the root.

Incomplete penetration is undesirable particularly if the root of the weld is subject to either direct tension or bending stresses. The unfused area permits stress concentrations which may result in failure without appreciable deformation. Even though the service stresses in the structure may not involve tension or bending at this point, the shrinkage stresses and consequent distortion of the parts during welding will frequently cause a crack to initiate at the unfused area. Such cracks may progress as successive beads are deposited until they extend through almost the entire thickness of the weld.

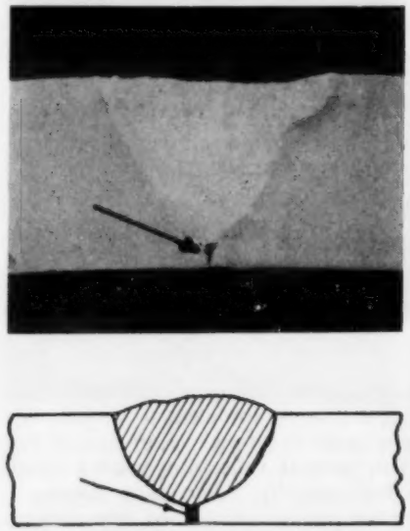


Fig. 16—Incomplete Penetration

Illustrating incomplete penetration in a groove weld.

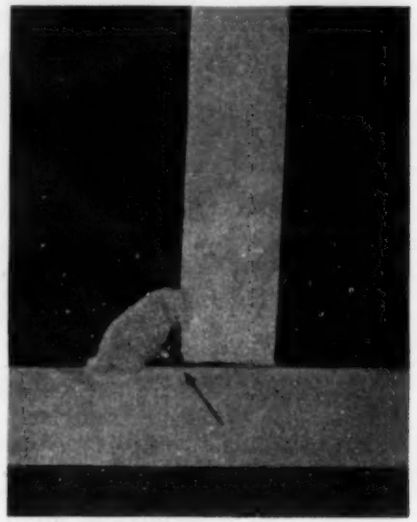


Fig. 17—Incomplete Penetration

Illustrating incomplete penetration in a fillet weld. This condition is often referred to as bridging.

The most frequent cause of this type of defect is a groove design not suitable for the welding process used or for the conditions of actual construction. When a groove is welded from one side only, complete penetration is not likely to be obtained consistently with the metal-arc process if the root face dimension is too great even though the root opening is adequate, or if the root opening is too small, or if the included angle of a V-type groove is too small. Any of these factors will make it difficult to

reproduce test results under conditions of actual construction. If the design is known to be adequate, incomplete penetration may result from the use of too large an electrode, an abnormally high rate of travel or the use of insufficient welding current.

1012. Undercutting

This term is used to describe either: the melting away of the sidewall of a welding groove at the edge of a layer or bead thus forming a sharp recess in the sidewall in the area to which the next layer or bead must fuse; or the reduction in base metal thickness at the line where the last bead is fused to the surface. Figures 18, 19 and 20 illustrate the presence of undercutting in both groove and fillet welds.

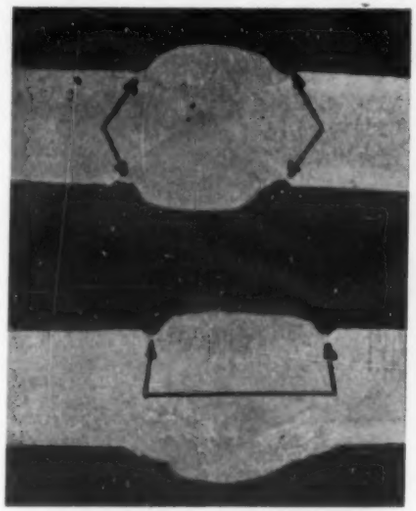


Fig. 18—Undercutting

Illustrating the presence of undercutting at the surfaces of groove welds.

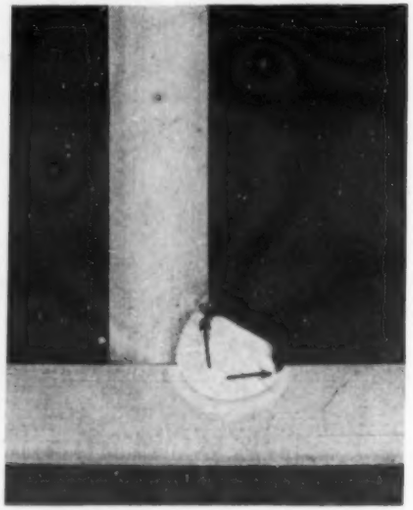


Fig. 19—Undercutting

Illustrating the presence of undercutting in a horizontal fillet weld.

Undercutting of both types is usually due to the technique employed by the operator. With a specific electrode too high a current or too long an arc may increase the tendency to undercut. However, different types of electrodes show widely varying characteristics in this respect. With some electrodes, even the most skilled operator may be unable to avoid undercutting under certain conditions. The conditions referred to involve position and accessibility of the joint primarily although magnetic arc blow may also be a factor. Magnetic arc blow is illustrated in Fig. 21.

Undercutting of the sidewalls of a welding groove will in no way affect the completed weld if care is taken to properly correct the conditions before depositing the next bead. This is best accomplished by using a well-rounded chipping tool or grinding wheel to eliminate the sharp recess which might serve to trap slag. However, if an operator is sufficiently experienced and knows to what extent subsequent beads will penetrate, chipping is not always necessary.

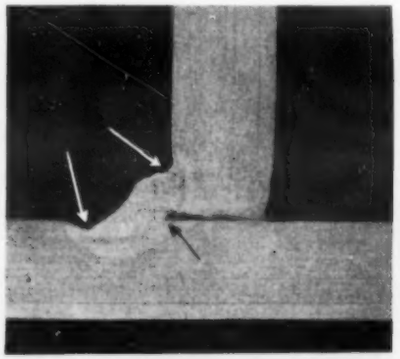


Fig. 20—Undercutting

Illustrating the presence of undercutting in an overhead fillet weld. Note also incomplete penetration.

Undercutting at the surface should not be permitted in an aggravated form as it may materially reduce the strength of the joint, particularly with regard to fatigue stresses. Fortunately this type of undercutting is always readily detectable by a visual examination of the surface of the completed weld and can usually be corrected by the deposition of additional metal.

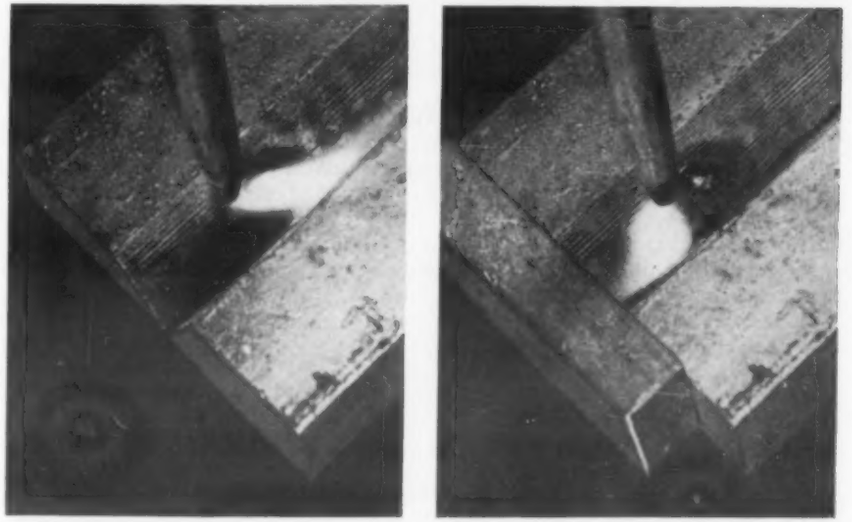


Fig. 21—Magnetic Arc Blow

Illustrating magnetic arc blow as encountered at the end of a joint (Left) and as controlled by use of a steel block (Right).

1013. Cracking

Cracking of welded joints results from the presence of localized stress which at some point exceeds the ultimate strength of the material. When cracks occur during, or as a result of, welding, little deformation is usually apparent.

It is well known that materials which will exhibit considerable ductility when subjected to uniaxial stress may, when subjected to two- or three-dimensional stresses, fail without appreciable deformation. Shrinkage caused by welding operations frequently sets up multi-directional stress systems. If because of such stresses a joint, or any portion of it, is incapable of sustaining appreciable deformation without failure, additional stresses set up in deposition of subsequent layers or in the welding of other joints may force that part to deform and cause failure. An example of stress pattern is shown in Fig. 22.

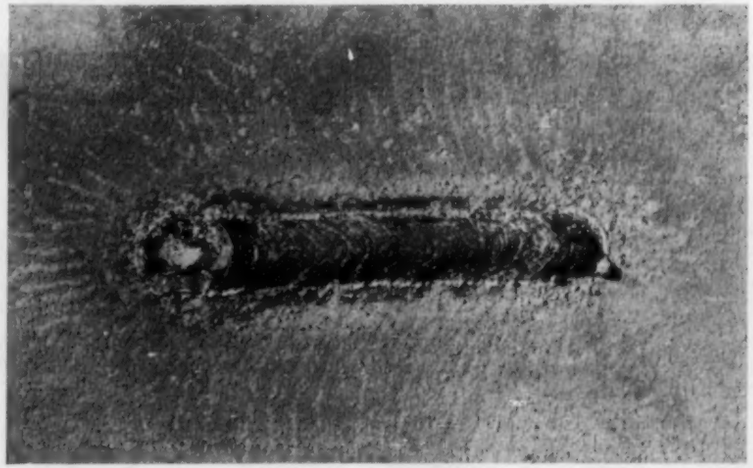


Fig. 22—Stress Pattern

Illustrating a stress pattern as shown by lines radiating from the weld where mill scale has cracked because the stresses produced by weld shrinkage have become excessive.

Cracks in welded joints which appear during welding are rarely caused by multi-directional stresses alone. However, experience has indicated that even though such stresses do not cause cracking, they may, particularly in the case of heavy or complicated structures, cause failure to occur with little deformation when additional load is applied. To avoid this undesirable condition, stress-relief heat treatment is usually specified for important structures fabricated of heavy material.

An unfused area at the root of a weld may result in cracks without appreciable deformation if this area is subjected to tensile stress. In welding two plates together the root of the weld is subjected to tensile stress as successive layers are deposited, and, as already stated, a partially fused root will frequently permit a crack to start which may progress through practically the entire thickness of the weld.

After a welded joint has cooled, cracking is more likely to occur if the metal is either hard or brittle. A ductile material will withstand stress concentrations which might cause a hard or brittle material to fail.

Weld Metal Cracking.—The ability of the deposit to remain intact under the stress system imposed during the welding operation is a function of the composition and structure of the weld metal. Cracking of the weld metal is more likely to occur in the first layer of the weld than elsewhere and unless repaired will in the majority of cases continue through the other layers as they are deposited. This tendency to continue into succeeding layers is either materially reduced or eliminated with austenitic weld metal. When the problem of cracking of the first layer of weld metal is encountered, improvement may be obtained by one or more of the following modifications:

(*a*) Change the electrode manipulation or electrical conditions, which will change the contour or composition of the deposit.

(*b*) Decrease the travel speed to increase the thickness of deposit, thereby providing more weld metal to resist the stresses being imposed.

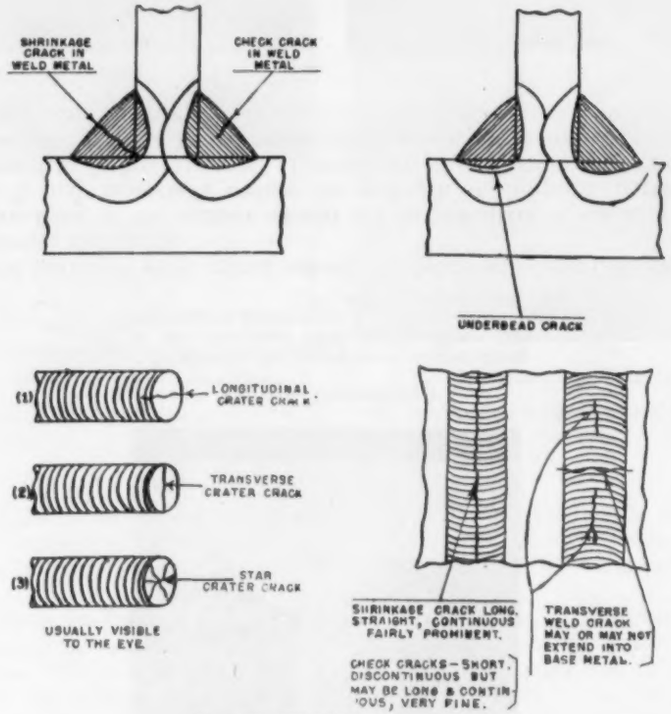

SHRINKAGE CRACK IN WELD METAL
CHECK CRACK IN WELD METAL
UNDERBEAD CRACK
(1)
LONGITUDINAL CRATER CRACK
(2)
TRANSVERSE CRATER CRACK
(3)
STAR CRATER CRACK
USUALLY VISIBLE TO THE EYE
SHRINKAGE CRACK LONG. STRAIGHT, CONTINUOUS FAIRLY PROMINENT.
CHECK CRACKS—SHORT, DISCONTINUOUS BUT MAY BE LONG & CONTINUOUS, VERY FINE.
TRANSVERSE WELD CRACK MAY OR MAY NOT EXTEND INTO BASE METAL.

Fig. 23—Weld Metal Cracks

Illustrating the different types of weld metal cracks.

(c) Use preheat to modify the intensity of the stress system being imposed.

Three different types of cracks, illustrated in Fig. 23, can occur in weld metal, as follows:

Transverse Weld Cracks.—These cracks are perpendicular to the axis of the weld and in some cases have been observed to extend beyond the weld into the plate metal. This type of crack is more common in joints having a high degree of restraint.

Longitudinal Weld Cracks.—These cracks are predominantly within the weld metal and are usually confined to the center of the weld. Such cracks may occur as the extension of crater cracks formed at the end of the weld. They may also occur as the extension through successive layers of a crack that existed in the first layer deposited. If a crack is formed in the first layer and is not removed or completely remelted when the subsequent layer is deposited, it tends to progress into the layer above and thence into the next adjacent layer and finally appears at the surface. The final extension of the crack to the weld surface may occur during the cooling of the weld after welding operations have been completed. This type of crack is illustrated in Fig. 24. For a specific electrode and base metal, variation in the electrical conditions or electrode diameter being used appears to be the only way of obtaining any improvement in this respect.

Fig. 24—Longitudinal Weld Crack

Crater Cracks.—Whenever the welding operation is interrupted there is a tendency for the formation of a crack in the crater. These cracks are usually star shaped and proceed only to the edge of the crater. However, they may be starting points for longitudinal weld cracks, particularly when they occur in the crater that is formed at the end of the weld. When the crater is formed at other places, as, for instance, when an electrode is changed, the crack is usually welded when the operation is resumed. This, however, does not always occur and sometimes fine star-shaped cracks may be observed at various places.

Base Metal Cracking.—This type of cracking, usually longitudinal in nature, which occurs within the heat-affected zone of the metal being welded, is almost always associated with hardenable materials. Hardness and brittleness in the heat-affected zone in welded joints are metallurgical effects produced by the thermal cycle of welding and are among the chief factors which tend to cause cracking. While a complete metallurgical discussion is beyond the scope of this handbook a rudimentary knowledge of the tendency of various groups of metals to harden or become brittle will be of value to the inspector. An illustration of underbead cracking which is associated with welding highly hardenable steels is shown in Fig. 25.

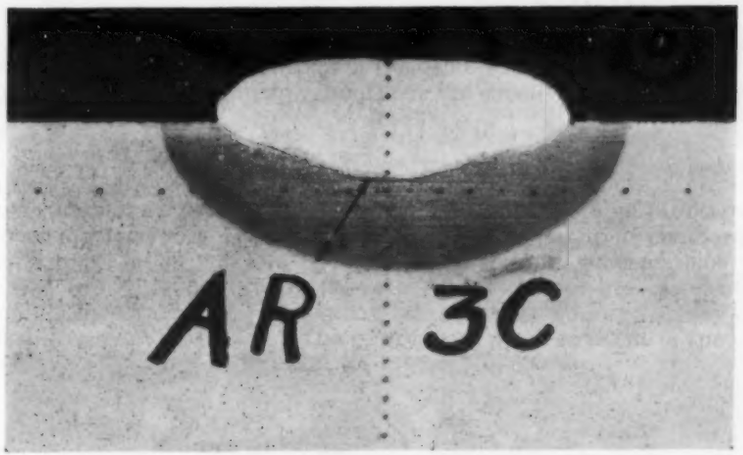


Fig. 25—Base Metal Cracking

Illustrating an underbead type of crack.

In the case of low-carbon, medium-carbon and low-alloy steels, it can be said that the hardness and the ability of a material to deform without rupture will depend upon the alloy group to which it belongs, and also upon the rate of cooling from the elevated temperatures produced by the welding operation. The rate of cooling will obviously depend upon a number of physical factors such as the temperature of the base metal; the thickness and thermal conductivity of the base metal; the heat input per unit time at a given section of the weld; and the atmospheric temperature. With a given cooling rate the low-carbon steels will harden considerably less than the medium-carbon steels. Low-alloy steels will exhibit a wider variation in their hardening characteristics and some of them may be similar to low-carbon steel while others will react like medium-carbon steel.

High-alloy steels must necessarily be given separate consideration since this group includes the austenitic and ferritic stainless steels and also includes the martensitic steels, which behave similarly to the medium-carbon and low-alloy groups except that they harden to a greater degree with a

given cooling rate. Neither the austenitic steels, of which the common 18% chromium–8% nickel stainless steel is an example, nor the ferritic stainless steels, of which the low-carbon straight chromium steels (or irons) containing 18% or more of chromium are an example, harden upon quenching from elevated temperatures. However, the ferritic stainless steels in general are rendered brittle (but not hard) by welding operations.

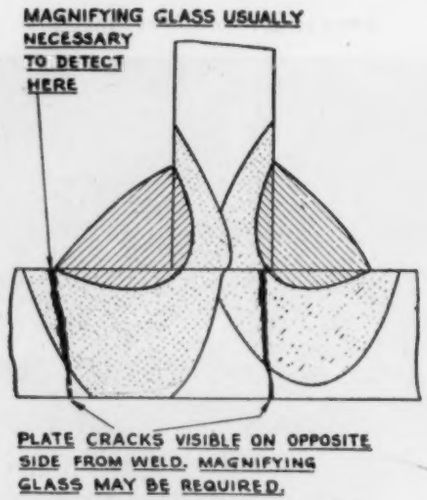

MAGNIFYING GLASS USUALLY NECESSARY TO DETECT HERE
PLATE CRACKS VISIBLE ON OPPOSITE SIDE FROM WELD. MAGNIFYING GLASS MAY BE REQUIRED.

Fig. 26—Base Metal Cracking

Illustrating base metal cracking which may occur at the root or toe of a fillet weld.

The metallurgical characteristics of the metals involved are of prime importance. Since ductility usually decreases with increasing hardness, base metal cracking has been associated with lack of ductility in the heat-affected zone. This is not the whole answer, however, for it has been established that different heats of the same steel of equal hardenability vary appreciably in cracking tendency. Furthermore, recent information establishes beyond a doubt that the characteristics of the electrode coating have a considerable effect upon the tendency toward heat-affected zone cracking.

Hardenable steels are usually more difficult to weld because of the two reasons which follow:

(*a*) Variations in metallographic structure of the heat-affected zone which can occur with variations in the cooling rate, resulting in differences in mechanical characteristics.

(*b*) Such steels are usually used because of their higher tensile properties and so can be likened to increasing the thickness of a mild steel.

When base metal cracking is encountered with hardenable steels improvement can be obtained in the following ways:

(*a*) The use of a suitable preheat.
(*b*) Increase in heat input which will retard cooling rate.
(*c*) Selection of best available electrode type.

This subject has been treated in a general manner. Each case usually involves requirements peculiar to the particular weldment in question.

Two types of base metal cracking can occur as a result of the welding operation. A description of each follows:

Transverse Base Metal Cracks.—This type of cracking which is transverse to the direction of welding is usually associated with fillet welds on steels of high hardenability where the distance between the edge of the weld and the exposed edge of one plate is relatively small. Such cracks usually cannot be detected until the weldment has cooled to room temperature.

Longitudinal Base Metal Cracks.—These cracks are parallel to the weld and are in the base metal. They may be extensions of fusion zone cracks. For fillet welds, longitudinal base metal cracks may be divided into two types:

(*a*) Toe cracks, which proceed from the toe of the fillet weld through the base metal often starting from the undercuts.
(*b*) Root cracks, which proceed from the root of the fillet weld and progress through the base metal being evident usually on the opposite side of the plate.

Figure 26 illustrates this type of crack.

In the case of groove welds, cracks are more likely to occur in the heat-affected zone adjacent to the weld. Cracks may also occur at the edge of the weld in the zone of fusion between the weld metal and base metal. Usually this type of crack is associated with steels of high hardenability when weld metal and plate metal are entirely different in composition, thereby promoting the formation of alloys of unpredictable properties in this zone.

1014. Surface Defects

Surface Holes.—Occasionally conditions are encountered during welding which result in holes in the surface of the deposit varying from a single hole every few feet to numerous holes per inch. Since the atmosphere produced by a given type of electrode is just as important a factor as the slag produced, for it determines arcing characteristics as well as having some effect upon slag composition, any change that varies the atmosphere will affect the results obtained. Such a change could be the difference between the air available at the arc when a pass is being deposited at the bottom of a narrow groove as compared to deposition of the top layer of the same weld. Eliminating from consideration the base metal which is being welded, which can be a factor, improvement is usually obtained through changing the electrical conditions, such as polarity and arc length. Figure 27 illustrates the presence of surface porosity in fillet welds. These are often referred to as pock marks.

The elimination of this type of defect is desirable since it can result in slag entrapment. When high-quality welding is being done it is not safe to assume that they will fuse out. Good welding practice dictates their elimination by chipping or grinding before deposition of succeeding layers.

Surface Irregularities.—Such irregularities as varying width of surface layer; depressions; variation in height of reinforcement; and nonuniformity of weld ripple, cannot properly be classified as weld defects. However, they are a part of the weld and are mentioned even though they may not affect the quality of the completed weld. Magnetic disturbance, poor technique and improper electrical conditions can account for these irregularities. Generally speaking, however, it usually reflects the ability and experience of the welding operator and as such is important. The more uniform the surface of a weld the better the eye appeal. Good welding finished in a poor manner should not be excused except under unusual conditions even though the integrity of the job is beyond question. Such unusual conditions might be: great magnetic disturbance; a bad location, that is, the operator is welding under a handicap either as to the position he must assume during welding or improper visibility; and other factors

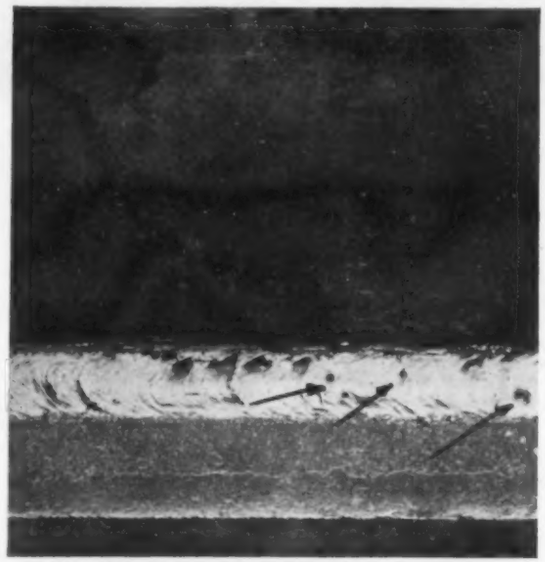


Fig. 27—Surface Holes

peculiar to a specific job. Figure 28 illustrates the surface appearance of welds produced under various electrical conditions and techniques. Figure 29 illustrates excessive spatter, and Fig. 30 illustrates poor surface appearance. Figure 31 illustrates satisfactory weld contours. See also Figs. 60 and 61 for satisfactory welds which are used as workmanship standards.

1015. Defective Properties (Weld Metal and Joint)

Specific mechanical and chemical properites are required of all welds made in any given weldment. The requirements depend upon the codes or specifications involved and departure from the specified requirements should be considered a defect. These properties in general are determined with specially prepared test plates although in some cases such tests may be made on sample weldments taken from production. Where test plates are used, the inspector must see that specified procedures are followed, otherwise the results obtained will not necessarily indicate the actual properties of the weldments.

Mechanical properties which may not meet prescribed requirements include tensile strength, yield strength, ductility, hardness or impact. Similarly chemical properties may be deficient because of incorrect weld metal composition or lack of corrosion resistance.

Defective Properties (Base Metal).—It should be pointed out that not all defects are due to improper welding conditions. Many such difficulties may be attributed to the base metal.

The base metal requirements are controlled by applicable specifications and departure from specified requirements should be considered a defect.

Properties which may not meet prescribed requirements include chemical composition; cleanliness (laminations, stringers); surface conditions (mill scale, paint, grease, oil, etc.); mechanical properties; and dimensions. Figure 32 illustrates the presence of laminations in rolled steel. The inspector will do well to keep these factors in mind when considering the causes of welding difficulties.

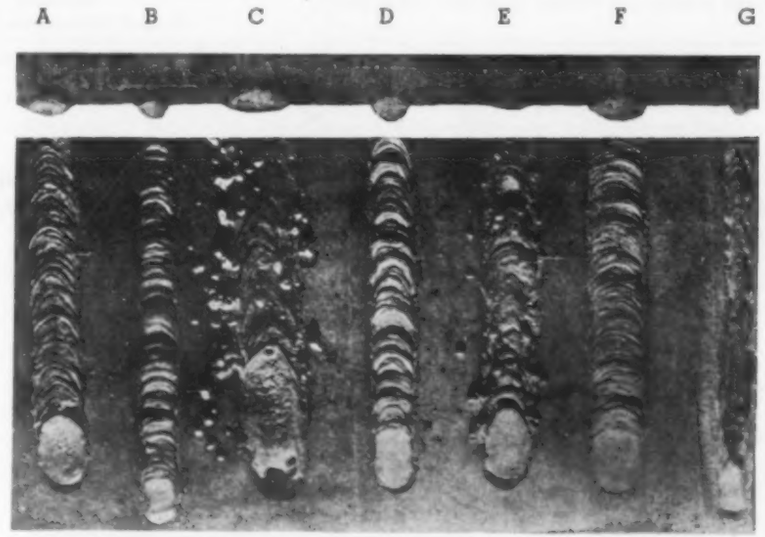


Fig. 28—Surface Appearance of Manual Metal Arc Beads

Specimens showing welds made using various procedures:
A—Weld made by proper procedure
B—Result of using too low an amperage
C—Spatter and undercut caused by excessively high amperage
D—Weld made using too low voltage
E—Weld made using excessively high voltage
F—Speed of travel too low
G—Speed of travel too high

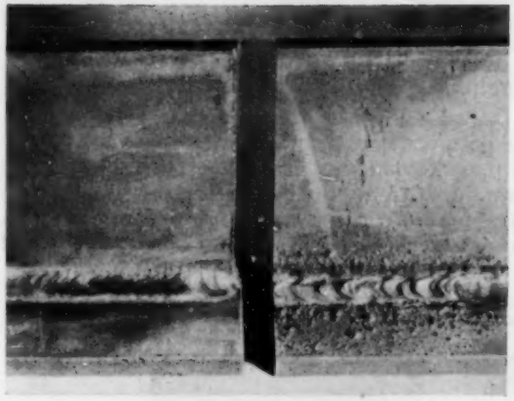


Fig. 29—Surface Appearance

Illustrating horizontal fillet weld having good surface appearance (Left) and having poor surface appearance (Right).

Fig. 30—Surface Appearance

Illustrating a vertical groove weld having poor surface appearance caused by improper welding technique (Right) as compared to a good-appearing vertical weld made with proper welding technique (Left).

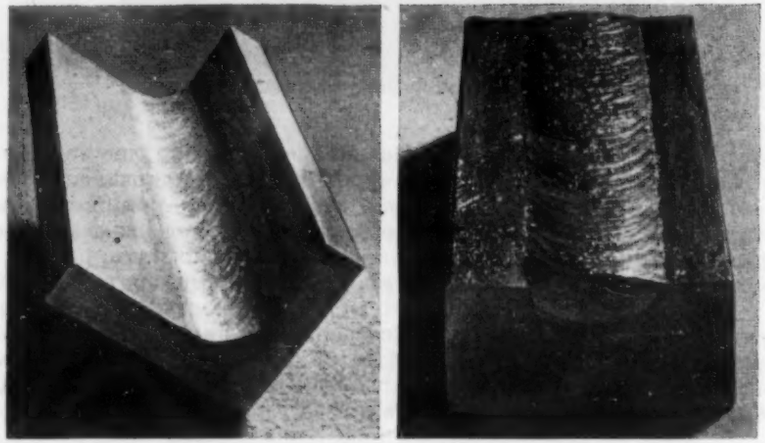


Fig. 31—Surface Appearance

Illustrating satisfactory weld contours and surface appearance.

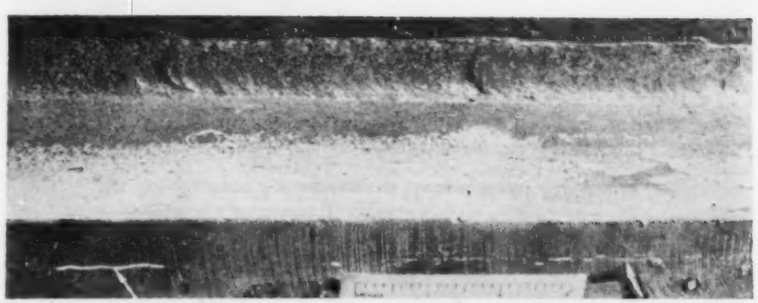


Fig. 32—Base Metal Defects

Illustrating the appearance of laminations (indicated by arrows) on the cut edge of a rolled plate.

1016. Methods of Testing

Table II indicates the usual methods of testing for the various defects discussed in this section. The test methods referred to are described in detail in Section XI.

Table II—Tests for Weld and Base Metal Defects

Defects	Methods of Testing
Dimensional Defects	
Warpage	Visual inspection with proper mechanical gages and fixtures
Incorrect joint preparation	Visual inspection with proper mechanical gages and fixtures
Incorrect weld size	Visual inspection with approved weld gage
Incorrect weld profile	Visual inspection with approved weld gage
Structural Discontinuities	
Porosity	Radiographic—Fracture—Microscopic—Macroscopic
Nonmetallic inclusions	Radiographic—Fracture—Microscopic—Macroscopic
Imperfect fusion	Radiographic—Fracture—Microscopic—Macroscopic
Undercutting	Visual inspection—Bend tests—Radiographic
Cracking	Visual inspection — Bend tests — Radiographic — Microscopic — Macroscopic — Magnetic particle — Penetrating oil
Surface defects	Visual inspection
Incomplete penetration	Radiographic—Fracture—Microscopic—Macroscopic
Defective Properties	
Low tensile strength	All-weld-metal tension test—Transverse tension test—Fillet weld shear test—Base metal tension test
Low yield strength	All-weld-metal tension test—Transverse tension test—Base metal tension test
Low ductility	All-weld-metal tension test—Free bend test—Guided-bend test—Base metal tension test
Improper hardness	Hardness tests
Impact failure	Impact tests
Incorrect composition	Chemical analysis
Improper corrosion resistance	Corrosion tests

SECTION XI—METHODS OF TEST FOR WELDS AND WELDED JOINTS

1101. Methods of Sampling

Sampling is the selection of samples for inspection purposes. There are two possibilities of application: namely, sampling of a production line or production lot and sampling of an individual weldment selected from the production line or production lot. In the first application, sampling may be "complete," meaning 100%, or "partial" in which case the frequency of selection is either "specified" or "random." These different methods of sampling are discussed below:

Complete Sampling means that the entire production lot of weldments or all weldments completed on a production line will be inspected. It does not necessarily mean that the welded joint of each weldment selected will be completely inspected or tested unless the inspection method prescribed is nondestructive, for it is obvious that were the inspection method a destructive one, complete sampling would result in no production. With the use of visual, radiographic or magnetic inspection methods complete sampling may be prescribed in which case the welded joints of each production weldment are completely inspected by the prescribed method or methods. Sampling of this type is used principally where insurance of highest quality is paramount. It is not generally adaptable to high-speed production because of the time and cost involved.

Partial Sampling means that certain weldments designated by sequence, frequency in which produced, or by a percentage of a lot, are to be inspected. The specified sequence, frequency or percentage as applying to the production line or production lot may or may not apply to the inspection of each weldment selected. It usually does not, as the amount of sampling or inspection per weldment selected will ordinarily be prescribed separately.

Specified Partial Sampling means that those particular weldments produced in the frequency or sequence prescribed are to be selected for inspection, e.g., every 10th starting with the first, or every 25th, etc. The sampling required per weldment may be prescribed by the drawings, in which case certain welded joints are indicated to be examined or the specific welds to be examined may be prescribed by the specification for the weldment.

This system has the psychological disadvantage that it discloses to the production organization in advance those items which are to be inspected so that special care may be taken to produce those parts so that they will be acceptable while giving less care to those which are not inspected. This method of selection may also be used where more rigid inspection of a particular joint or joints is required.

Random Partial Sampling means that a prescribed number of weldments to be inspected are to be selected from specified lots or groups of production, such as one in ten or twenty, or two in ten or twenty, etc. This selection may also be specified as a percentage of a lot thus permitting the inspector a choice within the range of the specified frequency. When this principle is applied to the weldment itself, a certain number of welded joints per weldment or a certain percentage of the welding may be prescribed again permitting the inspector a selection of the joints he will inspect by the inspection methods specified for the job.

By this method of sampling the inspector is permitted to sample, at specified frequencies without disclosing in advance, those specific items which he is going to examine. This system usually has a beneficial psychological effect on the production organization when intelligently applied because it does not emphasize the importance of any specific weldment as a production inspection sample. This system also gives the inspector an opportunity to find out where the lowest grade production is being done.

In most practical applications of sampling where several inspection methods are involved, complete sampling may be prescribed for visual inspection and, in the case of certain designated weldments, for radiographic and magnetic inspection. When proof tests are required, complete sampling may be specified. Usually, however, the inspection involves a combination of random partial and complete sampling.

Chemical and Metallographic Tests

1102. General

Tests are conducted for the qualification of welding procedures, the qualification of welding operators and for quality control. These tests may be chemical tests, metallographic tests or mechanical tests, or any combination of these. The tests generally specified are those which experience has shown to give assurance of the dependability of the weldment in subsequent service. The ideal test would, of course, be one which duplicates the service conditions exactly, but the difficulty of applying such tests because of time limitations and service variables is self-evident, and certain standard tests have therefore been evolved which give a reasonable assurance of satisfactory service.

The inspector has the responsibility of seeing that required tests are conducted properly and of passing judgment on the results of the tests. To do these properly, he should be thoroughly familiar with the proper methods of conducting the tests, the effect of defects on the test results and the interrelation of these defects in the test sample with the same types of defects in the actual weldment. With a thorough background in these, he will be able to use sound judgment in accepting or rejecting production work. No matter how carefully codes and specifications are written, much is left to the judgment of the inspector, and in fairness to himself, the manufacturer and his employer, he should equip himself with a thorough knowledge on which to base his decisions.

Brief descriptions of various types of standard tests applied to welds and weldments follow. The effect of defects on the results of these tests is briefly discussed. It is realized that much more could be written, but it is hoped that interested inspectors will avail themselves of opportunities for further study of the technical literature.

1103. Chemical Tests

Chemical tests ordinarily obtained are either for chemical analysis or corrosion resistance. Tests for chemical analysis are often required to ascertain whether the base metal and the weld metal meet the analysis requirements of the applicable codes or specifications. Special analyses of base metal and weld metal are used for special service requirements. Experience has shown what range of chemistry is best for a particular service condition. Oftentimes, trouble which can be traced by analysis to off-heats of metal is encountered in welding. This may be due to a high sulphur or phosphorus content, or to harmful residuals entering the metal from the scrap that was used. The over-all analysis of the material may be correct, but segregations of harmful elements may be present and give trouble. In these cases, careful methods of sampling for analysis must be used. In general, the analysis of the weld metal is specified to be in the same range as that of the base metal. Sometimes, however, a weld metal of greatly different analysis than that of the base metal is specified, depending on service requirements.

Since weldments must operate in all types of corrosive liquids, solids and gases, a large number of corrosion tests have been devised to check the material to see if it will meet required service conditions. The best test is actual use under service conditions, but time limitations and expense usually prohibit its application. Consequently, a large number of laboratory type tests have been evolved which give partial but satisfactory information. A few of the corrosive conditions to which weldments are subjected are under-soil attack of various types, salt water and salt spray, attack due to various atmospheres and waters, electrolytic and chemical action of all sorts, and high temperature conditions of various kinds.

Corrosion tests are required in but few codes and specifications as most metals are chosen for specific use by previous experience. The chemical industry, which is constantly handling new products, has evolved numerous corrosion tests which are usually required to be applied to the base metal and welded joints of weldments. Perhaps the best known test is the salt spray test. (Reference may be made to A.S.T.M. Standards, Part I, Metals, for a complete description of this test.)

Welds are made in a multiplicity of metals such as iron, nickel, copper, aluminum, magnesium and their alloys. All the above metals are used under specific corrosion conditions, and consequently a complete discussion of the various corrosion tests evolved is beyond the scope of this handbook.

1104. Metallographic Tests

Metallographic tests are not often required in welding specifications. They are carried out for various purposes such as:

(*a*) To determine the distribution of nonmetallic inclusions.
(*b*) To determine the number of weld passes.
(*c*) To determine the grain structure in the weld and fusion zone.
(*d*) To determine the extent and structure of the heat-affected zone.

They may involve merely visual examination, in which case the specimens,

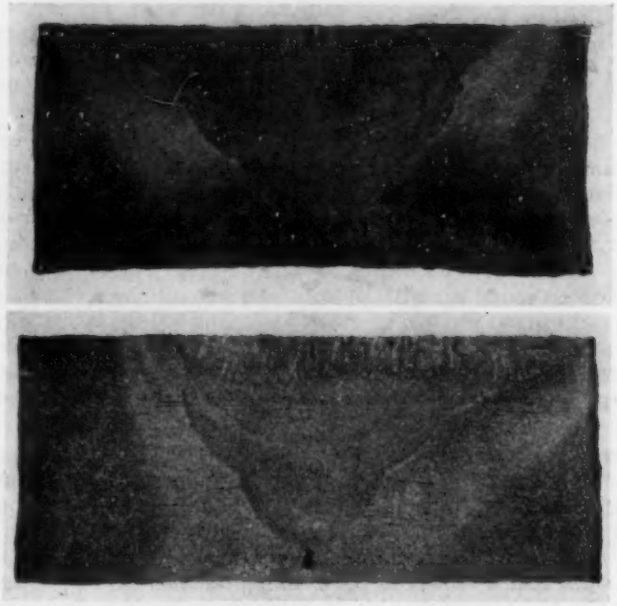


Fig. 33—Typical Photomacrographs

(Top) Sound weld cross section in $^{3}/_{4}$-in. thick steel plate. Note columnar grain structure of top and bottom beads and refined structure of all other beads. Also note diffused band on each side of weld denoting heat-affected zone. (Bottom) Same as top but with lack of penetration at root.

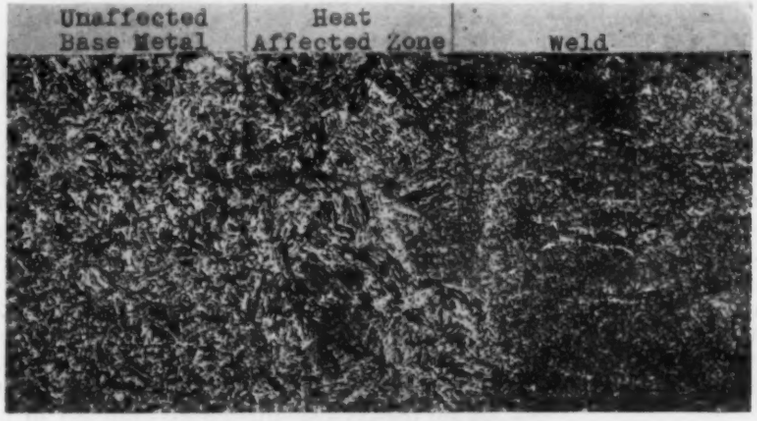


Fig. 34—Typical Photomicrograph

Illustrating the transition in structure from the weld metal to unaffected base metal.

called macro specimens, are etched to bring out the structure and examined by the unaided eye or at low magnifications; or they may involve microscopic examination, in which case the specimens, called micro specimens, are prepared and etched for examination under the microscope at high magnifications.

Sample and Sample Preparation.—Samples may be secured by sectioning the weld, or by means of a core drill or by trepanning. In the two latter cases the drilled hole or the trepanned cut may be rewelded and the weldment thus rendered fit for service. Such tests may be regarded as nondestructive.

Samples secured by any of the above methods are prepared by cutting to reveal a desired surface which is further prepared for examination.

There are two general types of examination: Macro, in which the sample is etched to reveal gross structure that can be studied by the unaided vision or with the assistance of a low power magnifying glass. Micro, in which the cut surface is etched to reveal fine structural details that can be seen only with the aid of a microscope.

For macroscopic examination, the surface to be examined may be prepared by one of the following methods:

(*a*) Without requiring any finishing or other preparation, place in boiling 50% solution of hydrochloric (muriatic) acid until there is a clear definition of the structure of the weld. This will require approximately one-half hour.

(*b*) Grind and smooth specimens with emery wheel or emery paper and then etch by treating with a solution of one part ammonium persulphate (solid) and nine parts of water by weight. The solution should be used at room temperature and should be applied by vigorously rubbing the surface to be etched with a piece of cotton kept saturated with the solution. The etching process should be continued until there is a clear definition of the structure of the weld.

(*c*) Grind and smooth specimens with emery wheel or emery paper and then etch by treating with a solution of one part of powdered iodine (solid form), two parts of powdered potassium iodide and three parts of water, all by weight. The solutions should be used at room temperature and should be brushed on the surface to be etched until there is a clear definition of the structure of the weld.

After being etched, the specimens are washed in clear water and the excess water removed. They are then immersed in ethyl alcohol and dried. The etched surfaces may then be preserved by coating with a thin, clear lacquer. Figure 33 shows some typical macro samples. (See also illustrations of weld defects in Section X.)

The specifications under which the weldment is constructed will define the type, sizes and number of defects allowable for the particular type of welded joint. Where a defect is located, additional specimens are usually cut at certain intervals on each side of the defective segment wherever the joint length will permit. If additional defects are found, more specimens are usually cut until the limit of the defective welding has been definitely established.

In the examination for exceedingly small defects or for grain structure at high magnification, specimens may be cut from the actual weldment, as above, or from welded test samples. The samples are prepared with a highly polished mirror-like surface and etched for examination under high-powered microscopes to show the structure of the base metal, heat-affected zone, fusion zone and weld metal. These specimens are called micro specimens and are most often specified for alloy steels or nonferrous metals. Figures 34 and 35 show some typical photomicrographs. Figures

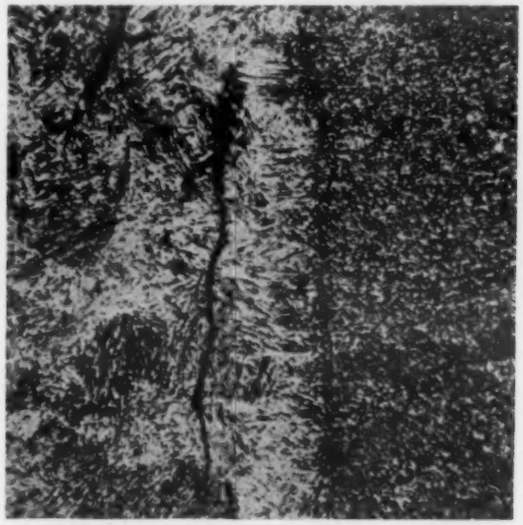


Fig. 35—Photomicrograph

Illustrating the appearance of a crack in the heat-affected zone (100 × approx.).

36 and 37 show micrographs and macrographs of the same weld. Samples such as these are required in but few codes and specifications, but are sometimes very useful in tracking down troubles encountered with welded joints or welds. A trained metallographer can read much from microscopic examinations. The procedure is complicated, since considerable skill is necessary in properly polishing the samples and in using the proper etchants and technique to show what is desired. (For a detailed discussion of microscopic examination procedures, reference may be made to A.S.T.M. Standards, Part I, Metals.)

Mechanical Tests

1105. Tension Tests

Tension tests are the most common of the mechanical tests. A large proportion of design is based on tensile properties and it is important that the tensile properties of the weld metal, of the bond between the base metal

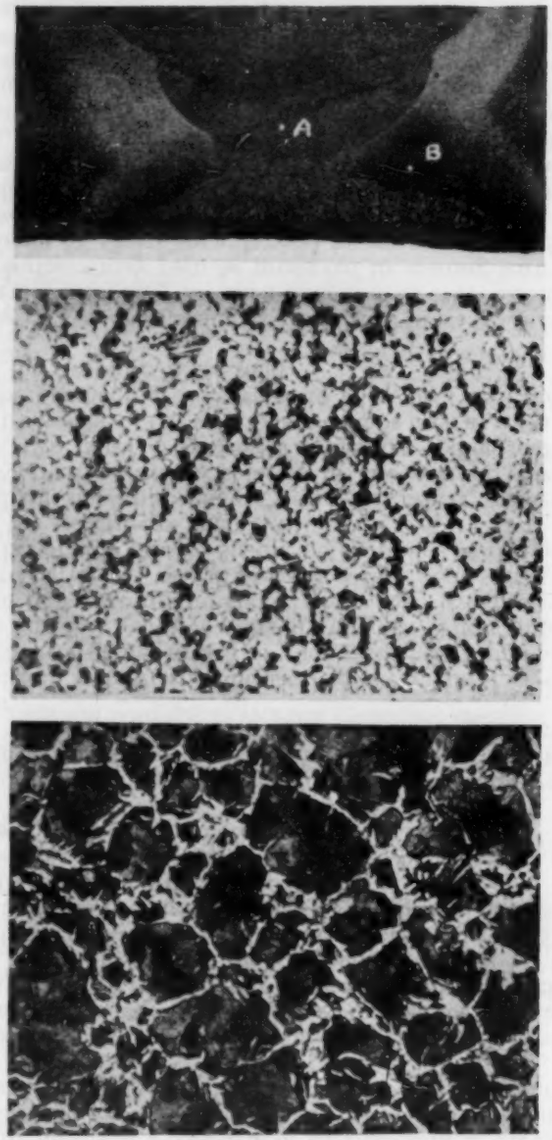


Fig. 36—Typical Photomacro and -micrographs

Illustrating the appearance of the same specimen when viewed at low and high magnifications.

Top view shows photomacrograph of welded joint.

Middle view shows weld metal, location *A* of top view, at 200 magnifications.

Bottom view shows heat-affected zone, location *B* of top view, at 200 magnifications.

and weld metal, and of the heat-affected zone, be known to conform to the design considerations of the weldment. Where butt joints are used, the weld metal should usually develop approximately the same tensile properties as the base metal although this is not required for many applications. In the case of fillet welds and plug welds, the shear strength is usually the significant factor.

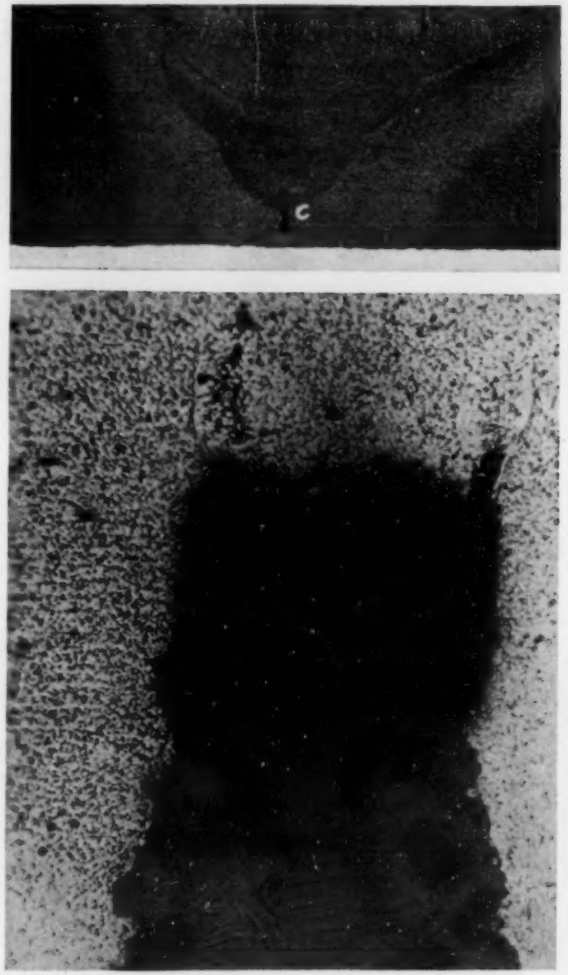


Fig. 37—Typical Photomacro and -micrographs

Illustrating the appearance of the same specimen when viewed at low and high magnifications.

Top view shows welded joint having incomplete penetration.

Bottom view shows same specimen, location *C*, at 100 magnifications.

There are three general types of tests used in determining tensile properties. These are:

(*a*) Standard 0.505-in. diameter or equivalent tests.
(*b*) Reduced-section tension tests.
(*c*) Fillet-weld shear tests.

1106. Standard 0.505-In. Specimen

The tensile properties determined by this test may be many, depending on the requirements of the specification. It may be necessary to determine the following:

(*a*) Tensile strength.
(*b*) Yield point or yield strength.
(*c*) Ductility (percentage elongation and percentage reduction of area).
(*d*) Proof stress.

The weld metal properties most generally required by specifications, however, are the first three, which will be described here briefly. See Fig. 38 for typical specimen. (Reference may be made to A.S.T.M. Standards, Part I, Metals for more detailed definition and explanation of the above properties, as well as for others not covered.)

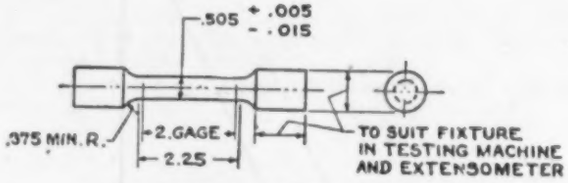


Fig. 38—Typical 0.505-In. Specimen

All dimensions in inches.

1107. Tensile Strength

This property is determined by pulling a standard 0.505-in. or similar specimen in a testing machine and noting the maximum load which the specimen withstands. The maximum load, divided by the original minimum cross-sectional area of the particular specimen, gives the ultimate tensile strength in pounds per square inch. A diameter of 0.505 in. was originally chosen as standard because that diameter gives a cross-sectional area of 0.200 sq. in., and it is merely necessary to multiply the maximum load by five to determine the ultimate tensile strength in pounds per square inch. For diameters other than 0.505 in. the cross-sectional area is determined by squaring the diameter and multiplying by 0.785.

1108. Yield Point and Yield Strength

To determine these properties a test is performed using the same type of specimen used in determining tensile strength.

1109. Yield Point

Yield point is defined as the load per square inch of the original cross-sectional area which causes a marked increase in extension without increase of the load. The yield point may be determined by one of the methods described in the following paragraphs:

Drop of the Beam Method.—In this method the load is applied to the specimen at a steady rate of increase and the operator keeps the beam in balance by running out the poise at approximately a steady rate. When the yield point of the material is reached, the increase of load stops, and the beam of the machine drops for a brief but appreciable interval of time. In a machine fitted with a self-indicating load-measuring device, there is a sudden halt of the load-indicating pointer corresponding to the drop of the beam. The load at the "halt in the gage" or the "drop of the beam" is recorded, and the corresponding stress is taken as the yield point. This method of determining the yield point requires only one operator to conduct a test.

Divider Method.—In this method the observer, with a pair of dividers or other suitable apparatus, watches for visible elongation between two gage marks on the specimen. When visible stretch is observed, the load at that instant is noted, and the stress corresponding to the load is taken as the yield point.

Total Strain Method Using Extensometer.—An extensometer reading to 0.0001 inch per inch of gage length is attached to the specimen at the gage marks. When the specimen is in place and the extensometer attached, the load is increased at a uniform rate. The observer watches the elongation of the specimen as shown by the extensometer and notes for this determination the load at which the rate of elongation shows a sudden increase.

NOTE: The first two methods described above give similar values for the same material. The third method is more sensitive and may show the start of the yield elongation at a slightly lower stress than that given by the other methods.

1110. Yield Strength

Yield strength may be defined as the load per square inch of cross-sectional area which caused a specified set as determined by either of the following methods:

Offset Method.—For nearly all metals, if at any point on the stress-strain diagram, the load is released, the curve of decreasing load will be approximately parallel to the initial portion of the curve of increasing load. (See Fig. 39 for a typical stress-strain diagram.) These curves may, however, be offset by a distance which is the approximate value of the permanent set after the release of load. The value of this set is expressed in terms of the percentage of original gage length. Thus, yield strength may be determined by the "offset method" as follows: On the stress-strain diagram shown in Fig. 39, a straight line is drawn parallel to the initial straight line

portion of the diagram and at a distance to the right corresponding to the value of set specified. The load corresponding to the point where this straight line intersects the initial curve divided by the original cross-sectional area of the specimen is the value of the "yield strength." In reporting values of yield strength obtained by this method, the specified value of offset used should be stated in parentheses after the term yield strength. Thus "52,000 Yield Strength (0.2%)" indicates that at a stress of 52,000 psi. the approximate permanent set of the metal is 0.2% of the original gage length. This method is devised for determining a stress corresponding to a well-marked plastic deformation.

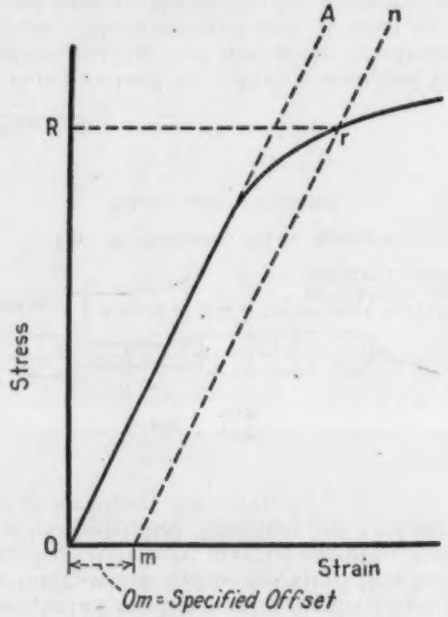


Fig. 39—Typical Stress-Strain Diagram

Illustrating typical stress-strain diagram used in the offset method.

Extension Under Load Method.—For tests to determine the acceptance or rejection of material whose stress-strain characteristics are well known from previous tests of similar material in which stress-strain diagrams were plotted, the total strain corresponding to the stress at which the specified permanent set occurs will be known within satisfactory limits. Therefore, in such tests a specified total strain may be used, and the stress on the specimen, when this total strain is reached, is the value of the yield strength. To determine yield strength by this method the initial reading of the extensometer for the initial load is recorded, and the load increased until the extension in the specimen is that prescribed. The corresponding load divided by the original cross-sectional area of the specimen is the yield strength.

1111. Ductility

Ductility or percentage elongation and reduction of area may also be obtained with a 0.505-inch type specimen. The ductility values are not usually used in designing a structure, but, nevertheless, minimum values are included in most specifications because they are an indication of the quality of the weld metal.

Percentage elongation is obtained by placing gage marks on the specimen (usually using a double center punch with the points accurately distanced to the gage length required) before testing. After testing, the broken bar is fitted tightly together and the final distance between gage marks measured. The difference between the final and original gage lengths, divided by the original gage length and multiplied by 100, gives the percentage elongation in the specified gage length. Sometimes, because of defective machining or some other factor, the specimen will not break in the center portion of the gage length, and may even break completely outside of the gage length. In such cases the test results are usually not acceptable because the majority of elongation has taken place at a position other than where originally intended.

Reduction of area is obtained by carefully fitting together the ends of the fractured specimen and measuring the dimensions of the smallest cross section. The difference between this area and the original cross-sectional area, expressed as a percentage of the original area, is defined as the reduction of area.

1112. All-Weld-Metal Tension Tests

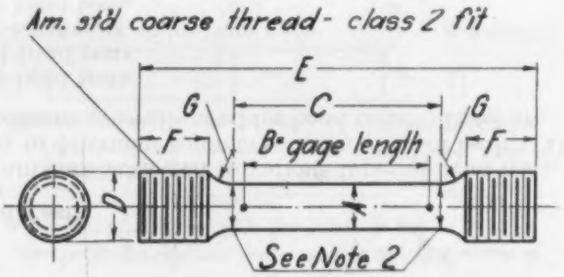
This test, used to determine the tensile properties of welds, is generally taken longitudinally so that only deposited weld metal is obtained within the gage length. The specimen may be etched before machining so that it can be properly chucked to include only deposited metal. Figure 40 illustrates a typical all-weld-metal specimen.

Defects such as porosity, lack of fusion, slag inclusions and cracks may affect the tensile properties adversely, depending on their size and location. Lack of fusion and porosity generally lower the tensile and yield strength only slightly unless the area of defect is large or unless they are located near the surface. The effect of such defects on ductility, however, may be significant, particularly if these defects are located near the surface.

1113. Reduced-Section Tension Test

The tensile property determined by reduced-section tension tests is generally the ultimate tensile strength, although yield strength and ductility may also be determined. Figure 41 shows a typical specimen. This test is usually used to determine the properties of the weld metal, the bond between the weld metal and base metal, and the heat-affected zone. The weld, fusion and heat-affected zones should usually develop the minimum tensile strength of the base metal, but if the specimen fails in the base metal, the test is usually not considered to have failed. The original minimum cross-sectional area should be carefully determined so as to determine

final values in pounds per square inch. Where ductility is specified, a gage



Specimen	Dimensions of Specimen						
	A, In.	B, In.	C, In.	D, In.	E, In.	F, In.	G, In., Min.
C-1	0.500 ± 0.01	2	2 1/4	3/4	4 1/4	3/4	3/8
C-2	0.437 ± 0.01	1 3/4	2	5/8	4	3/4	3/8
C-3	0.357 ± 0.007	1.4	1 3/4	1/2	3 1/2	5/8	3/8
C-4	0.252 ± 0.005	1.0	1 1/4	3/8	2 1/2	1/2	1/4
C-5	0.126 ± 0.003	0.5	3/4	1/4	1 3/4	3/8	1/8

Fig. 40—Typical All-Weld-Metal Tension Specimen

NOTE 1: Dimensions *A*, *B* and *C* usually as shown, but alternate shapes of ends may be used.

NOTE 2: It is desirable to have the diameter of the specimen within the gage length slightly smaller at the center than at the ends. The difference should not exceed 1% of the diameter.

NOTE 3: Dimensions *E* and *F* may suit fixture in testing machine and extensometer.

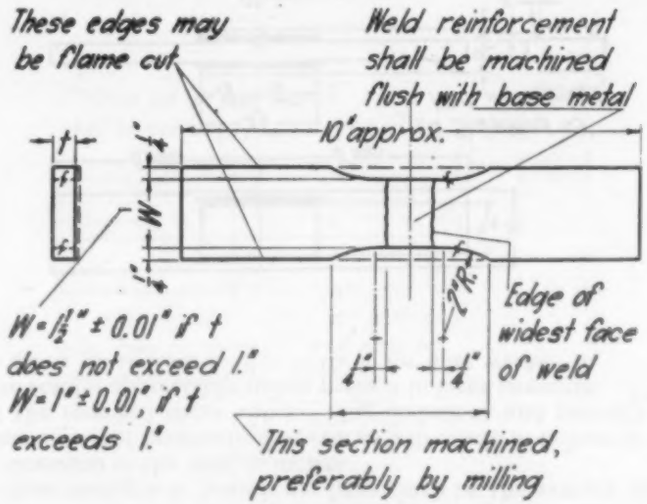

These edges may be flame cut
Weld reinforcement shall be machined flush with base metal
10" approx.
t
W
1"
W = 1 1/2" ± 0.01" if t does not exceed 1"
W = 1" ± 0.01", if t exceeds 1"
2" R.
1/4"
1/4"
Edge of widest face of weld
This section machined, preferably by milling

Fig. 41—Typical Reduced-Section Tension Specimen

final values in pounds per square inch. Where ductility is specified, a gage length, usually 1/8 in. less than the width of the weld, is lightly scribed on the face of the weld, and measured before and after testing. Weld reinforcements are usually removed prior to these tests.

The required radius of the reduced section varies with different codes and specifications. The edges of the reduced section may be parallel for a considerable distance, or a rather sharp radius may be specified to confine the fracture to the weld metal. If the radius is small, and the minimum width is confined to a short length, the stress built up on pulling the specimen will accumulate in this minimum width and give high tensile results. As the radius is increased, a truer tensile value is obtained. This type specimen is designed to cause failure in the weld metal. Other type samples have a reduced section for the full width of the weld, and some base metal on each side, in which case failure may occur in either the weld metal, heat-affected zone or base metal. Defects which are present will lower the tensile properties in the same manner as described for the 0.505-in. type tension test. (See Paragraph 1106.)

1114. Shear Tests

Shear tests are used only for fillet welds or plug welds. The fillet weld tests may be on transverse shear specimens similar to that shown in Fig. 42, or on longitudinal shear specimens similar to that shown in Fig. 43. The dimensions of the base metal should be such that fracture will take place in the weld metal when the specimen is subjected to tensile loading. The maximum load to fracture the specimen is noted. The shear strength of the weld, in pounds per linear inch, is then obtained by dividing the maximum load by twice the width of the specimen for the transverse test, and by the sum of the lengths of fractured weld for the longitudinal test. The shear

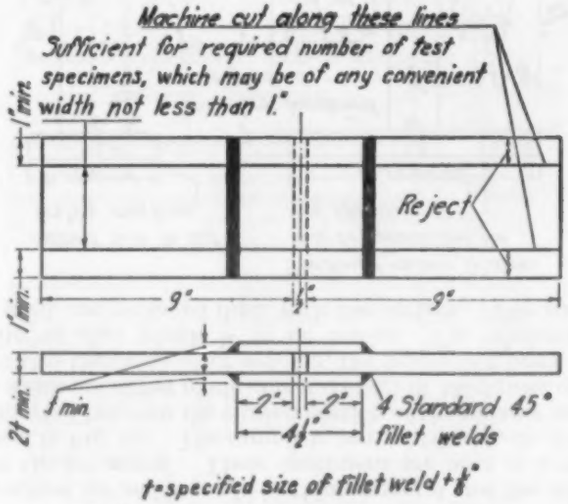
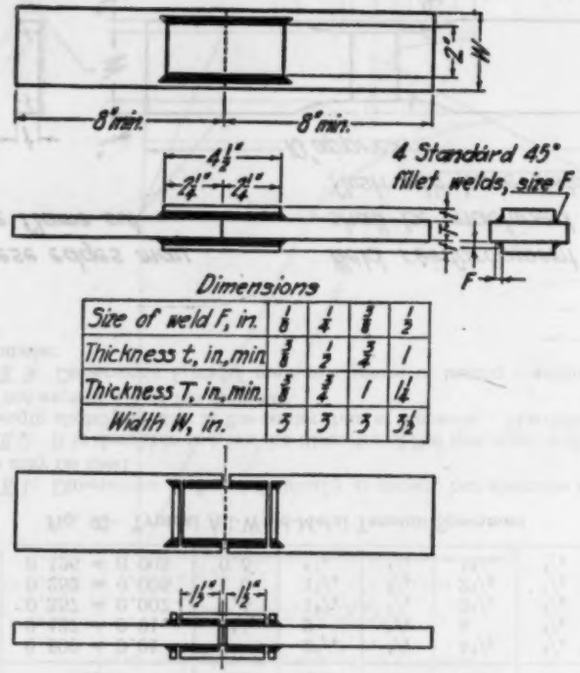


Fig. 42—Typical Transverse Shear Specimen

strength of the weld, in pounds per square inch, may be obtained by dividing the shear strength in pounds per linear inch by the average theoretical throat dimension of the weld in inches.

Excessive lack of penetration or cracks will result in failure of the weld to meet the required shear value. Slag inclusions and porosity will not affect the results appreciably unless present in large amounts. Plug welds are also given shear tests similar to those for fillet welds.



Size of weld F, in.	1/8	1/4	3/8	1/2
Thickness t, in., min.	3/8	1/2	3/4	1
Thickness T, in., min.	5/8	3/4	1	1¼
Width W, in.	3	3	3	3½

Fig. 43—Typical Longitudinal Shear Specimen

Illustrating specimen before machining (Top) and after machining (Bottom).

1115. Bend Tests

Welded joints are subjected to various types of bend tests, the purpose being usually to determine soundness or ductility, or both. There are four types of specimens generally used for bend tests. These are:

(*a*) Face-bend tests.
(*b*) Root-bend tests.
(*c*) Side-bend tests.
(*d*) Free-bend tests.

Face-, Root- and Side-Bend Tests.—Generally, the face- and root-bend tests are specified for welds made in thinner metal and the side-bend test specified for thicker metal. These specimens are bent in a standard jig, such as shown in Fig. 44. The sample is bent until a 1/32-in. diameter wire cannot be inserted between the curved portion of the plunger and the specimen. The welds are either made in metal of 3/8-in. thickness, or, if heavier, machined to this thickness after welding, the machining being done on the side opposite to that which is to be tested. The reinforcements and backing, if used, are removed flush with the surface. The surface on the

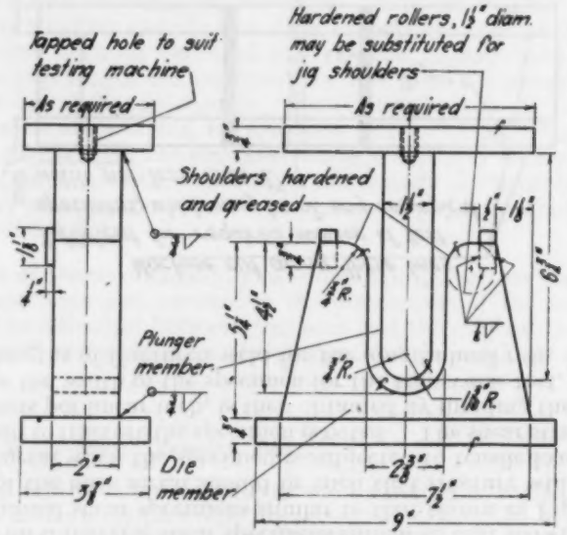


Fig. 44—Guided-Bend Test Jig

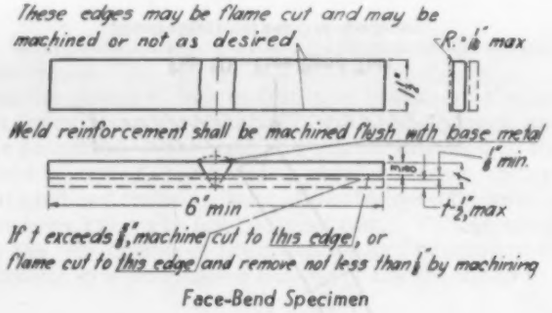
Dimensions shown are for 3/8-in. specimens. Diameter of plunger member and width of gap sometimes varied for other specimens.

tension side of the specimen is ground or filed transverse to the direction of welding, and the longitudinal edges of the specimen rounded to a radius approximately one-tenth the thickness. Figures 45 and 46 show typical specimens. In preforming this test, the weld is placed at mid-span on the jig. In the root-bend test, the root of the weld is directed toward the gap; in the face-bend test, the face of the weld is directed toward the gap. In the case of a side-bend test, the side showing the greater defects, if any, is placed toward the gap.

Any specimen in which a crack or other open defect is present after bending, exceeding a specified size measured in any direction, is considered to have failed. Cracks occurring on the corners of the specimen during testing are not considered unless they exceed a certain specified size. Figure 47 shows two specimens which have been tested, illustrating a sound weld and one which has failed. If the weld metal is not clearly defined so that the weld can be properly centered in the bending jig, the surface may be lightly etched. (See Paragraph 1104 for recommended etchants.)

These edges may be flame cut and may be

(d) Free-bend tests.


These edges may be flame cut and may be machined or not as desired
R. = 1/8" max
1/8"
Weld reinforcement shall be machined flush with base metal
1/8" min.
6" min
t-1/2", max
If t exceeds 3/8", machine cut to this edge, or
flame cut to this edge and remove not less than 1/8" by machining
Face-Bend Specimen

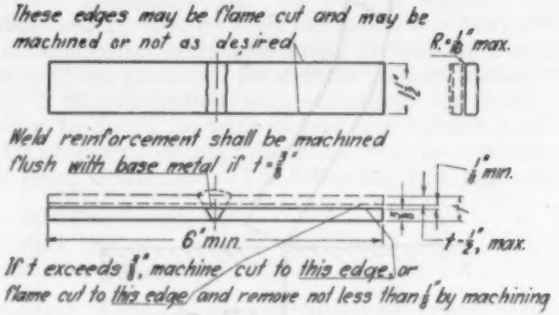
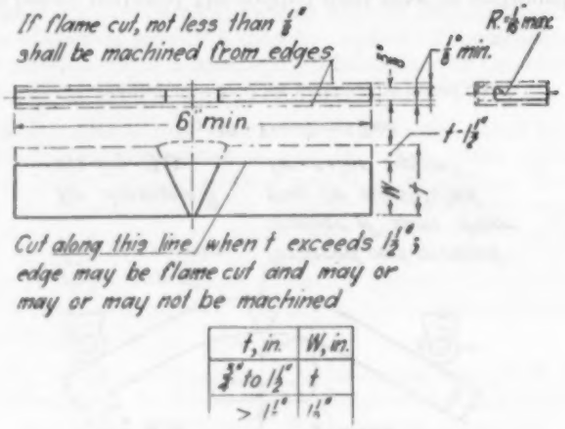

These edges may be flame cut and may be machined or not as desired
R. = 1/8" max.
1/8"
Weld reinforcement shall be machined flush with base metal if t = 3/8"
1/8" min.
6" min.
t-1/2", max.
If t exceeds 3/8", machine cut to this edge, or
flame cut to this edge and remove not less than 1/8" by machining
Root-Bend Specimen

Fig. 45—Typical Face- and Root-Bend Specimens


If flame cut, not less than 1/8" shall be machined from edges
R. = 1/8" max.
1/8" min.
6" min
t-1/2"
W
t
Cut along this line when t exceeds 1 1/2"; edge may be flame cut and may or may or may not be machined

t, in.	W, in.
3/8" to 1 1/2"	t
> 1 1/2"	1 1/4"

Fig. 46—Typical Side-Bend Specimen

be lightly etched. (See Paragraph 1104 for recommended etchants.)

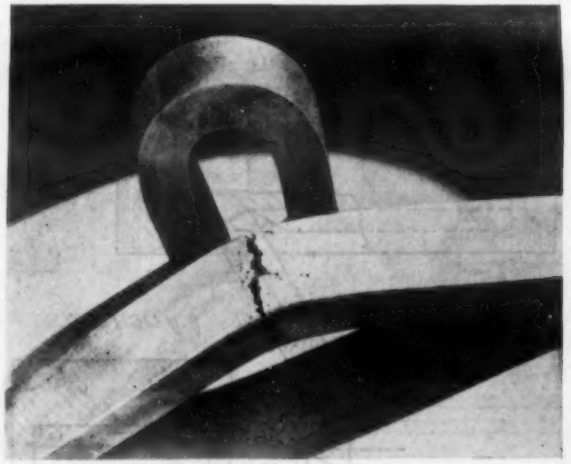
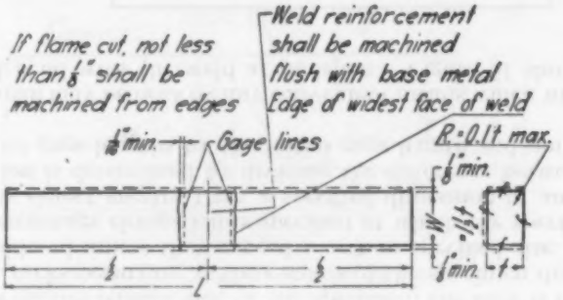


Fig. 47—Guided-Bend-Test Specimens

Illustrating a sound face-bend specimen (Top) and one which has failed (Bottom).

Free-Bend Test.—In addition to the above soundness tests, a free-bend test is also sometimes specified, the main purpose being to determine ductility, although at the same time the weld is given a severe soundness test. The free-bend specimen is generally the full thickness of the material being welded, and the width is usually $1^1/_2$ times the thickness as shown in Fig. 48.



t, in.	1/4	5/16	1/2	5/8	3/4	1	1 1/4	1 1/2	2	2 1/2
W, in.	3/8	9/16	3/4	15/16	1 1/8	1 1/2	1 7/8	2 1/4	3	3 3/4
L min, in	6	8	9	10	11	12	13 1/2	15	18	21
B* min, in	1 1/4	1 1/4	1 1/4	2	2	2	2	2	2	3

*See fig. 49

Note:- the length L is suggestive only

Fig. 48—Free-Bend Specimen

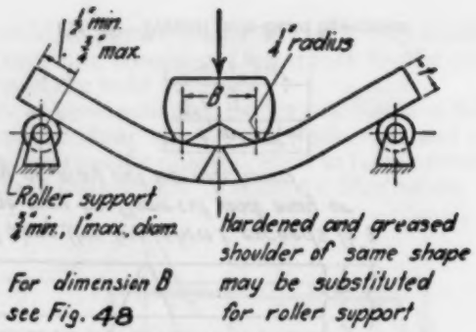

1/2" min.
3/4" max.
1" radius
B
Roller support
3/4" min., 1" max. diam.
Hardened and greased shoulder of same shape may be substituted for roller support
For dimension B see Fig. 48

Fig. 49—Free-Bend Test

Illustrating a method for making the initial bend.

For welds in heavy material, the welded joint may be sectioned through its thickness into several specimens, each of which is tested. Weld reinforcements and backing, if used, are removed. The tension side of the specimen is ground or filed smoothly transverse to the direction of welding, and the longitudinal edges of the specimen rounded. Gage lines are lightly scribed on the face of the weld (the wider face if the two faces are of unequal width), the gage length used being approximately 1/8 in. less than the width of the face of the weld. The specimen is bent with the weld at midspan. If the weld cannot be distinguished readily the specimen may be lightly etched. The specimen is bent initially using a device or method similar to that shown in Fig. 49, through an angle of from 30 to 45°, so that the specimen may be bent symmetrically.

Compressive forces are then applied to the ends of the specimen, continuously decreasing the distance between the ends, as shown in Fig. 50.

When either a crack or other defect exceeding a specified size in any direction appears on the tension side of the specimen, the load is immediately removed. Cracks occurring at the corners of the specimen during testing are not considered unless they exceed a certain specified size. Usually a minimum percentage elongation is specified at which the specimen should not show any defect greater than a specified dimension in any direction. The elongation is determined by dividing the difference between the final and the initial gage lengths by the initial gage length and multiplying by 100.

The specimen may be bent by any convenient means which will produce a symmetrical bend with the weld at midspan. Figure 51 shows a jig for

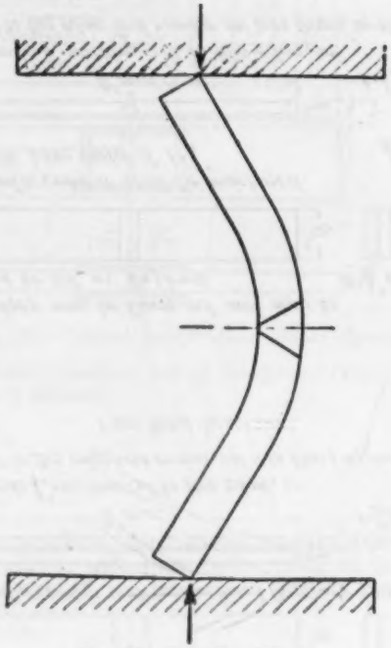


Fig. 50—Free-Bend Test

Illustrating final bend of specimen.

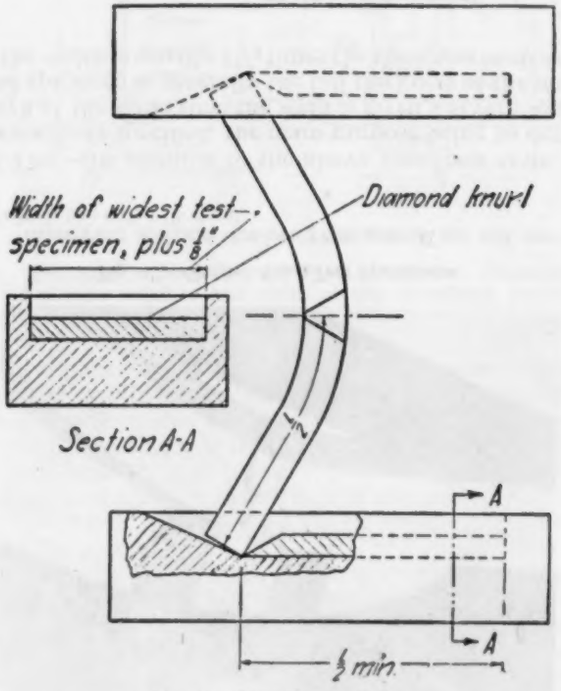


Fig. 51—Free-Bend Test

Illustrating a device for accomplishing the final bend.

bending this type of specimen. This jig eliminates the possibility of slipping of the specimen.

Defects such as porosity, lack of fusion or cracks on the tension side of the specimen, even though very small, will tend to open and propagate readily. The soundness of the weld and quality of fusion to the base metal are thus severely tested. Specimens obtained from test plates which have been X-rayed and found to have allowable defects, such as very slight porosity, have been known to fail the bend test. This occurs if the defects are at or near the tension side of the specimen and bending of the specimen, during test, results in a progressive tearing of the specimen to failure.

1116. Fracture Tests

Fracture tests of many types have been evolved to test welds and weldments. They are designed so that the path of fracture will be through the weld, either transversely, to show the fusion and heat-affected zone in addition to the weld metal, or longitudinally through the center of the weld. The fractures are then examined for defects such as cracks, porosity, lack of fusion, depth of penetration, and sometimes for fiber. A means is usually provided to direct the path of fracture through a desired section. This is done by properly locating notches in order to concentrate the stress at the desired point of fracture. The following three tests are used:

(*a*) Fillet-weld-break test.
(*b*) Nick-break test.
(*c*) Nick-break-fracture test.

Fillet-Weld-Break Test.—A typical fillet-weld-break test specimen is shown in Fig. 52. A force is applied to the specimen, as shown in Fig. 53, until rupture occurs. This force may be applied by any convenient means such as a press, testing machine or hammer. The surface of the fracture is then examined for defects.

Nick-Break Test.—A typical nick-break test specimen is shown in Fig. 54. The specimen is supported as shown in Fig. 55 and ruptured by a force which, unless otherwise specified, may be applied either slowly or suddenly as by one or more blows of a hammer. The surface of the fracture is then examined for defects.

Nick-Break-Fracture Test.—One typical specimen used for the nick-break-fracture test is illustrated in Fig. 56. A fracture made with one sharp blow of a steam hammer or drop weight is preferable. Severity of the test may be increased greatly by chilling the specimen before testing. The fractured surface should be examined for visible defects in the weld and base metal. Steel quality may be evaluated by the amount of shelving.

A fracture test provides a simple means of distinguishing certain characteristics which have an important bearing on the impact resistance of steel. These characteristics are:

Steel Quality.—The examination of a fractured surface is a means of detecting macro-defects in the section through which the fracture occurs. Visible defects are easily recognized. For example, elongated inclusions in rolled steel show up as shelves on the fractured surface and the quality of the steel may be determined by the number and continuity of such shelving.

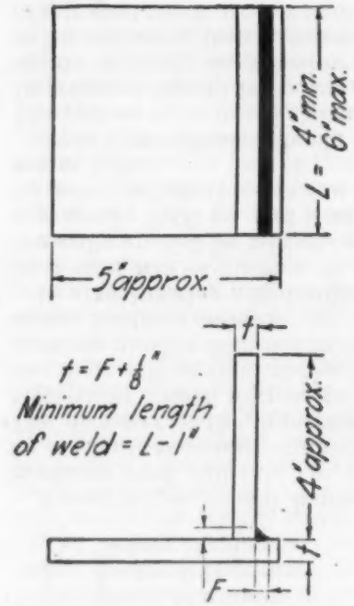


Fig. 52—Typical Fillet-Weld-Break Specimen

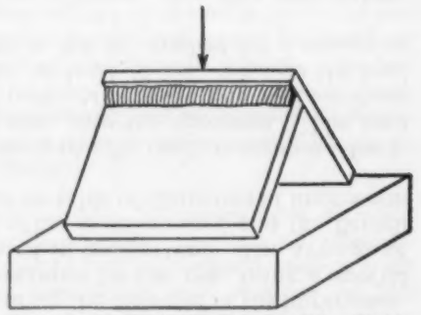


Fig. 53—Method of Rupturing Fillet-Weld-Break Specimen

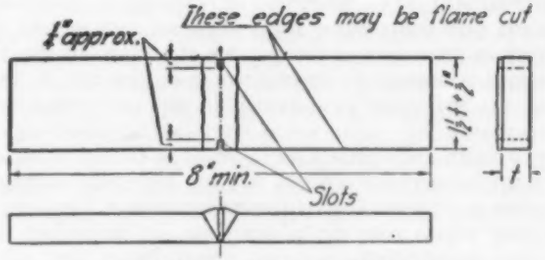


Fig. 54—Typical Nick-Break Specimen

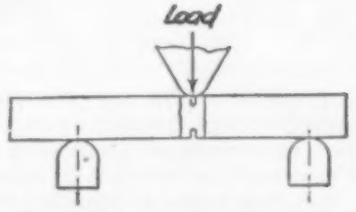


Fig. 55—Method of Rupturing Nick-Break Specimen

Fiber.—If fracture occurs without deformation, it is characterized by a bright crystalline multi-faceted surface. This type of fracture is evidence of low impact resistance of the steel for the specific conditions under which the fracture was made. A high energy of impact is characterized by deformation at the fractured surface and a dull gray surface appearance. Increased severity of notching, increased velocity of impact or decreased temperature of testing may cause a change in appearance of the fracture from fibrous to crystalline. Therefore, in applying and interpreting a fracture test, it is necessary to consider what is to be reasonably expected in the way of notches, impact or low-temperature conditions for a specific application.

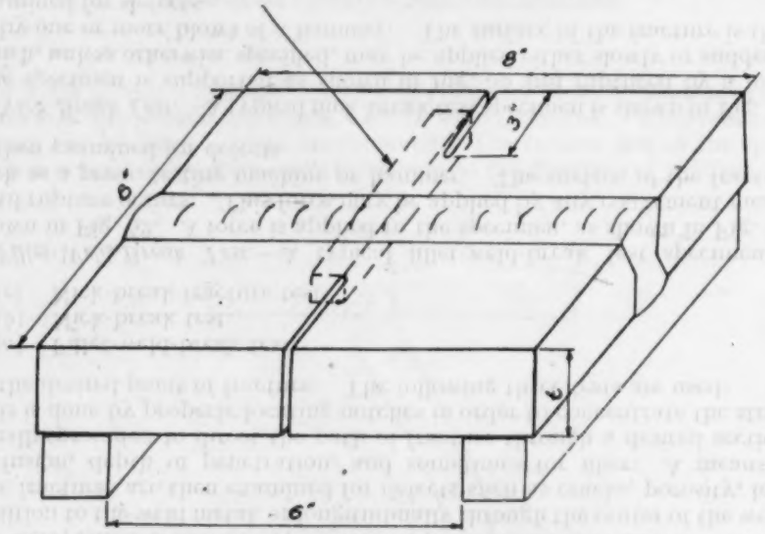

1/2 x 1/2 x 4-in. bar used as striking block.
1 x 6 x 6-in. plate placed on top of bar to prevent damage to steam hammer or drop weight.
8"
3"
6"
t
t
6"

Fig. 56—Nick-Break-Fracture Test of Welded Joint

t = thickness of plate. Support on 6-in. span; break with one blow of drop weight or steam hammer. Cut notch with hack saw or abrasive wheel.

In general, a steel which can be suitably heat treated (quenched to martensite and properly tempered) is much superior in fracture test performance to the same steel which has not been adequately heat treated. However, steel of very low hardness and tensile strength usually has good impact resistance and a fibrous structure even though not properly heat treated.

For weldments designed to resist high static or impact loads or multi-axial stresses, particularly under low-temperature service conditions, a fibrous fracture may be required throughout the weld, heat-affected zone and base metal. This requirement may usually be obtained by using base and filler metals with adequate alloy content (hardenability) for the particular heat-treating and welding practices involved. The nick-break-fracture test may then serve as a simple and practical shop control test. It should not be applied to ordinary constructional steels which are welded in the as-rolled or normalized condition where crystalline fractures are normally encountered although the steel is satisfactory for design requirements.

1117. Hardness Tests

Hardness is affected by the analysis of the base metal and weld metal, the metallurgical effects of the welding process, cold working of the metal, heat treatment and many other factors. Experience has dictated that limitations be placed on the hardness of the base metal, heat-affected zone and weld metal of certain metals, usually alloy steels. If too hard, they will not have sufficient ductility for the service conditions, their corrosion resistance may be impaired or some other factor may dictate this limitation.

It is not the purpose, here, to cover fully the numerous methods of measuring hardness and the application of each, for the field is a large one and many of the methods are mainly of academic interest. It is desirable, however, to cover the three most widely used methods of measuring hardness and briefly mention their limitations and the factors which must be considered to obtain true readings. Portable machines using the same or very similar principles are often used, and the inspector should acquaint himself with the use and limitations of the several types. The three most widely used methods of hardness measurement are:

(*a*) Brinell Hardness.
(*b*) Rockwell Hardness.
(*c*) Vickers Hardness.

Brinell.—The Brinell hardness test consists of impressing a special hardened steel ball into the specimen under test, using a definite load for a definite time and accurately measuring the diameter of the impression. The diameter of the impression is measured by the eye, using a special high-power Brinell microscope graduated in millimeters. The average of two diameters at right angles to each other is determined and the Brinell hardness number obtained from a chart or table of diameters of impression versus hardness number.

In actual testing a hydraulic machine is usually used to impress a hardened steel ball of 10 mm. ± 0.0025 mm. into the specimen. The load is usually applied by a hand-operated pump or wheel. The load for steels is generally 3000 kg. and is applied for at least 15 sec., whereas the load for softer metals (brasses and bronzes) is 500 kg. applied for a similar or longer time.

Several precautions should be taken to insure obtaining true values. The surface to be tested should be flat and reasonably free from scratches. Impressions should be taken at representative locations. The specimen should be firmly supported in such a way that the load is applied normal to the surface of the specimen. The test should not be used on specimens of soft steel which are less than about 1/2 in. thick, or on specimens so small

as to produce flow of metal at the edges as a result of the ball impression. Impressions should not be taken closer than about two diameters from each other or the cold work due to the previous impression will give an erroneous result. As there may be some sticking of the mechanism in the hydraulic, hand-operated machine, the pumping should be done more slowly as the maximum load of 3000 kg. is approached.

Rockwell.—The Rockwell hardness tester measures the depth of residual penetration made by a small hardened steel ball or a diamond cone. The test is performed by applying a minor load of 10 kg., which seats the penetrator in the surface of the specimen and holds it in position. The dial is turned to the point marked "Set," and the major load then applied. After the pointer comes to rest, the major load is released, leaving the minor load still on. The Rockwell hardness number is read directly on the dial.

As Rockwell hardness numbers are based on the difference between the depths of penetration at major and minor loads it will be evident that the greater this difference, the less the hardness number and the softer the material. This difference is automatically registered when the major load is released (the minor load still being applied) by a reversed scale on the indicator dial, from which the Rockwell hardness number may be read directly. Hardened steel balls of $^1/_8$ in. or $^1/_{16}$ in. diameter are used for the softer metals and a cone-shaped diamond penetrator used for hard metals. Various major loads are also applied, depending upon the material, thickness, depth of penetration allowable, etc. Table III shows the various Rockwell scales and penetrators used. The B and C scales are the ones most generally used.

Table III—Rockwell Hardness Scales

Letter*	Penetrator	Major Load, Kg.	Dial Figures
A	Diamond	60	Black
B	$^1/_{16}$-in. ball	100	Red
C	Diamond	150	Black
D	Diamond	100	Black
E	$^1/_8$-in. ball	100	Red
F	$^1/_{16}$-in. ball	60	Red
G	$^1/_{16}$-in. ball	150	Red
H	$^1/_8$-in. ball	60	Red
K	$^1/_8$-in. ball	150	Red

* Designation of scales.

Several precautions should be taken to insure obtaining true values. Surfaces that are ridged by rough grinding or coarse machining offer unequal support to the penetrator. Both the surface at the penetrator side and the underside should be free of perceptible ridges. The specimen should seat solidly, with no rocking, and should be of such thickness that the underside of the specimen does not show a perceptible impression. This thickness will vary greatly according to the hardness of the material tested. Softer material requires greater thickness of specimen, or lighter load, or both. Results from tests on a curved surface may be in error and should not be reported without stating the radius of curvature. In testing round specimens, the effect of curvature may be eliminated by filing a small flat spot on the specimen. Impression should not be made within about two diameters of the edge of the specimen, or closer than that to each other. When changing from one scale to another, a standard test block of a specified hardness in the range of the new scale should be used to check whether all the required changes have been made and whether the penetrator has properly seated. Care should be taken not to damage the penetrator or the anvil by forcing them together when a specimen is not in the machine. The minor load should be applied carefully so as not to overshoot the mark. The loading lever should be brought back gently. The ball penetrator tends to become flattened by use, especially in testing hardened steels, and should be checked occasionally and replaced when necessary. In the same manner, the cone penetrator should be examined and replaced when found to be blunted or chipped.

Vickers.—The Vickers hardness test consists of impressing a diamond penetrator into the surface of a specimen under a predetermined load. The ratio of the impressed load to the area of the resulting indentation gives the Vickers hardness number. The application and removal of the load, after a predetermined interval, are controlled automatically. Since the Vickers indenter is a diamond, it can be used in testing the hardest steels and remains practically undeformed. The load is light, varying from 1 to 120 kg. according to requirements. A normal loading of 30 kg. is used for homogeneous materials, and 10 kg. is used for soft, thin or surface hardened materials. One movement of a starting handle releases the mechanism, and the depression of a foot pedal restores it to its original position. An audible click informs the operator of the duration of the test. It is recommended that the time of load application be standardized at 10 sec.

Upon lowering the stage, the measuring microscope may be swung into a position over the impression. The impression appears as a dark square on a light background. The measurements are taken across the diagonals of the square between the knife edges. There are three knife edges: one is fixed, another movable by means of a micrometer screw connected to the counting mechanism, and the third provided for rapid readings to specified limits. The left-hand corner of the impression is set to correspond to the fixed knife edge, the movable knife edge adjusted to coincide with the right-hand corner of the impression, and the reading obtained directly from the indicator. The actual hardness figure is then found from a chart or calculated by a simple formula.

Hardness numbers obtained with a pyramid indenter are practically constant, irrespective of the load applied. The Vickers and Brinell hardness values on steel are practically identical up to a hardness of about 300. At higher hardness values the Brinell number falls progressively lower than the Vickers number, and is not reliable above about 600 Brinell hardness, even with specially hardened balls. This irregularity is caused by the flattening of the steel ball under the heavy local loads required for testing hard materials, whereas the diamond shows no distortion. As Vickers impressions are much smaller than those obtained when using Brinell or Rockwell testers, the surfaces to be tested should be prepared much more carefully. Although the Vickers instrument is definitely a machine of precision, it requires care in operation rather than any particular skill.

It is advisable to check the machine occasionally with standard test blocks. In case of failure to check satisfactorily, the trouble may be

Table IV—Typical Hardness Conversion Table (Approx.)

Rockwell Hardness		Vickers Hardness*	Brinell Hardness†		Tensile Strength, 1000 Psi.	Rockwell Hardness		Vickers Hardness*	Brinell Hardness†		Tensile Strength, 1000 Psi.
C—150 Kg. Load, Diamond	B—100 Kg. Load, 1/16 Ball	Diamond Pyramid	Tungsten Carbide Ball	Steel Ball		C—150 Kg. Load, Diamond	B—100 Kg. Load, 1/16 Ball	Diamond Pyramid	Tungsten Carbide Ball	Steel Ball	
67	...	918	820	...	...	20	98.9	240	231	225	107
66	...	884	796	...	...	19‡	98.1	235	226	220	106
65	...	852	774	...	...	18	97.5	231	222	215	103
64	...	822	753	...	...	17	96.9	227	218	210	102
63	...	793	732	...	...	16	96.2	223	214	206	100
62	...	765	711	...	...	15	95.5	219	210	201	99
61	...	740	693	...	...	14	94.9	215	206	197	97
60	...	717	675	...	...	13	94.1	211	202	193	95
59	...	694	657	...	...	12	93.4	207	199	190	93
58	...	672	639	...	...	11	92.6	203	195	186	91
57	...	650	621	...	...	10	91.8	199	191	183	90
56	...	630	604	...	...	9	91.2	196	187	180	89
55	...	611	588	...	...	8	90.3	192	184	177	88
54	...	592	571	...	...	7	89.7	189	180	174	87
53	...	573	554	...	283	6	89	186	177	171	85
52	...	556	538	...	273	5	88.3	183	174	168	84
51	...	539	523	500	264	4	87.5	179	171	165	83
50	...	523	508	488	256	3	87	177	169	162	82
49	...	508	494	476	246	2	86	173	165	160	81
48	...	493	479	464	237	1	85.5	171	163	158	80
47	...	479	465	453	231	0	84.5	167	159	154	78
46	...	465	452	442	221	...	83.2	162	153	150	76
45	...	452	440	430	215	...	82	157	148	145	74
44	...	440	427	419	208	...	80.5	153	144	140	72
43	...	428	415	408	201	...	79	149	140	136	70
42	...	417	405	398	194	...	77.5	143	134	131	68
41	...	406	394	387	188	...	76	139	130	127	66
40	...	396	385	377	181	...	74	135	126	122	64
39	...	386	375	367	176	...	72	129	120	117	62
38	...	376	365	357	170	...	70	125	116	113	60
37	...	367	356	347	165	...	68	120	111	108	58
36	...	357	346	337	160	...	66	116	107	104	56
35	...	348	337	327	155	...	64	112	104	100	54
34	...	339	329	318	149	...	61	108	100	96	52
33	...	330	319	309	147	...	58	104	95	92	50
32	...	321	310	301	142	...	55	99	91	87	48
31	...	312	302	294	139	...	51	95	86	83	46
30	...	304	293	286	136	...	47	91	83	79	44
29	...	296	286	279	132	...	44	88	80	76	42
28	...	288	278	272	129	...	39	84	76	72	40
27	...	281	271	265	126	...	35	80	72	68	38
26	...	274	264	259	123	...	30	76	67	64	36
25	...	267	258	253	120	...	24	72	64	60	34
24	...	261	252	247	118	...	20	69	61	57	32
23	...	255	246	241	115	...	11	65	57	53	30
22	100.2	250	241	235	112	...	0	62	54	50	28
21	99.5	245	236	230	110	...					

Footnotes on opposite page.

due to the plunger sticking in the sleeve. Polish the tube or plunger carrying the diamond indenter in a longitudinal direction with dry emery paper (400 C).

Precautions:

(*a*) Apply test only to smooth level surfaces representative of the metal.
(*b*) Select the load with regard to hardness and thickness of the piece to be tested.
(*c*) Replace the diamond when it becomes chipped as shown by irregularity of the impression made.
(*d*) Check the zero position of the micrometer occasionally.
(*e*) Adjust the knife edges of the micrometer accurately, perpendicular to the diagonals of the impression.
(*f*) Keep the dashpot full of suitable oil to prevent impact loading.
(*g*) Discard readings made on a tilted surface, which are indicated by a large difference between two diagonal readings.

Summary.—Each of the above types of hardness test supplements each other. The Brinell impression, being large, can only be used for obtaining hardness values over a relatively large area such as the face of a weld or the base metal. The Rockwell test and Vickers test, however, can be applied to survey the hardness of small zones such as the cross section of a weld, the heat-affected zone or various individual beads. Conversion data from Rockwell to Brinell to Vickers are available. Table IV shows a typical conversion chart. In using this chart, however, it should be remembered that it is obtained from a large number of tests and gives an average value, the scattering obtained in the actual tests being considerable, depending greatly on the analyses of materials and their condition.

1118. Impact Tests

Since welds must often withstand impact or suddenly applied loads, it is natural that impact test specimens have been devised for welds and welded joints. Impact tests of welded specimens are required by codes and specifications in several European countries. Impact tests in the codes and specifications used in the United States at present are generally limited to Ordnance weldments. The velocity of the impact, the presence of sharp notches, and the temperature of the metal, are factors that contribute to the ability of the material to withstand shock. As metals respond in a different degree to these factors, it is usually desirable to compare metals under two or more different conditions which are related to the service requirements.

* Vickers hardness values obtained with following loads:

	Kg.
918 to 171, inclusive	50
167 to 95, inclusive	30
91 to 62, inclusive	10

† Brinell hardness values obtained with 3000-kg. load except tungsten carbide ball values 159 to 86, inclusive, obtained with 1500-kg. load and from 83 to 54, inclusive, with 500-kg. load.

‡ Rockwell C values below 20 are not recommended for correlation; however, these values are sufficiently accurate to indicate the trend of relationship.

It is well known that certain steels may become quite brittle at low temperature, and this likewise applies to certain weld metals. Consequently, some codes and specifications require impact tests to be made on all-weld-metal samples or welded joint samples at the lowest temperature that the weldment may be subjected to in its ordinary service. Ordnance weldments which are subjected to high velocity impacts in service may also be tested under similar conditions. These tests may be welded joint specimens or full-size weldments, and in some cases are tested ballistically to more closely simulate true service conditions.

The impact testing, as described here, however, is limited to the more generally used small specimens. The usual test consists of the determination of the energy absorbed in breaking a notched specimen by a single blow. The specimen is usually notched to produce an intense concentration of stress as a test condition.

Mechanics of the Test.—The essentials of an impact test are a suitable specimen; a moving mass of known kinetic energy which must be great enough to break a test specimen placed in its path; an anvil or support on which the test specimen is placed to receive the blow of the moving mass; and a device for measuring the residual energy in the moving mass after the specimen has been broken.

Types of Test.—Three types of impact test are used where specimens are broken in a testing machine. These are:

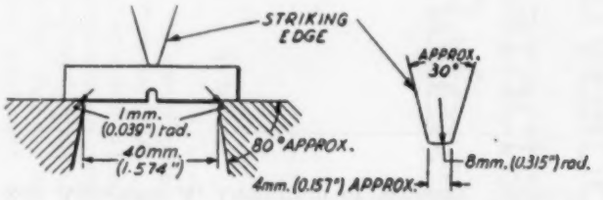
(*a*) Simple beam test (Charpy).
(*b*) Cantilever beam test (Izod).
(*c*) Tension-impact test (Charpy Tension).

In the usual Charpy test, the specimen is in the form of a notched beam. The notched face is placed on two anvils with the notch equally distant from the anvils. It is struck at a point opposite the notch by the tup of a pendulum. In the Izod test, the specimen is notched and clamped in a vise at the level of the notch. The free end is struck by the tup of a pendulum. In the Charpy Tension test, the specimen is attached to the pendulum and carries a tup which engages the anvils. The direction of the force is parallel to the axis of the specimen while in the two previous tests it is perpendicular. Figure 57 illustrates typical methods for the simple beam and cantilever impact tests.

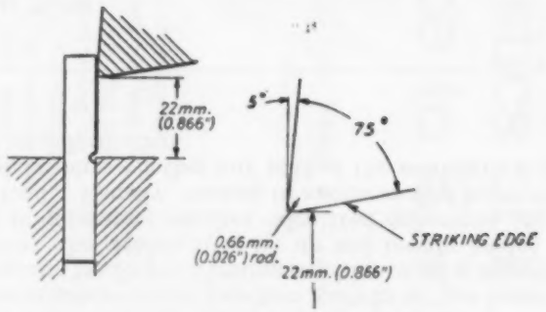
Types of Specimens.—The simple beam and tension-impact tests may be made on unnotched specimens, if indicated by the characteristics of the material tested, but the cantilever beam test is not often suitable for other than notched specimens. In both types of beam tests, the specimen, when notched, is struck so that the root of the notch is in the region of the tensile beam stress. The specimens may be all-weld-metal samples or samples including the weld and cut from welded joints. If notched, the notch may be placed to concentrate the test in various directions in the weld or in the heat-affected zone of the base metal. Figure 58 shows several methods of removing specimens from welded joint samples. Figure 59 illustrates typical specimens showing the specimen and notch dimensions.

Reports of impact tests should include the following:

(*a*) Type of impact test.
(*b*) Type of specimen and notch used.
(*c*) Location of the notch.
(*d*) Temperature of the specimen or of the room if both are the same.
(*e*) The energy actually absorbed by the specimen in breaking, reported in total foot-pounds as the "impact value" of the specimen. This value is read directly from the calibrated scale on the impact testing machine.



Simple Beam Test.



Cantilever Beam Test.

Fig. 57—Typical Impact Tests

1119. Proof Tests

General.—Proof tests of weldments can be made to determine whether the weldment will withstand the application of service loading without failure or acquiring a permanent deformation in any part. Such tests are usually designed to subject the parts of the weldment to stresses above those which they are expected to carry in service, but below the elastic strength of the metal. The manner in which such tests are applied varies with the type of weldment and the service for which it is designed. In most cases proof tests are applied in connection with visual examination or at least some visual examination is required in proof testing. Details of any proof tests required are usually specified by the drawings, specifications or contract for the weldment.

Closed Containers.—For proof testing of closed containers some form of internal pressure is usually used. This pressure may be obtained by apply-

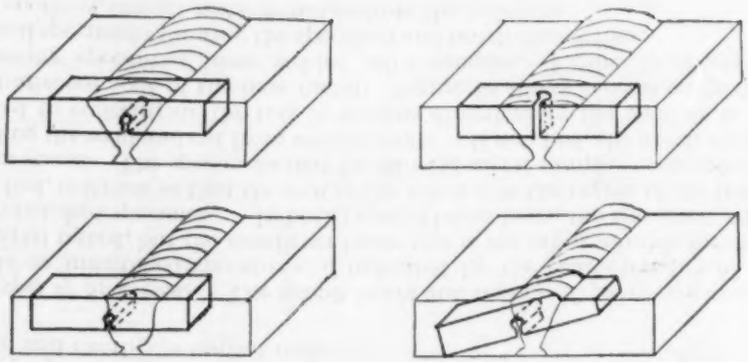
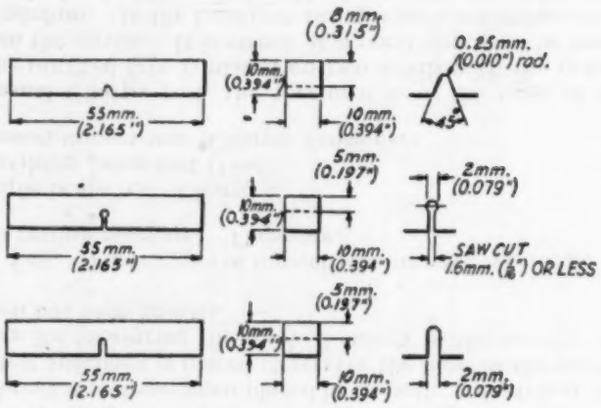
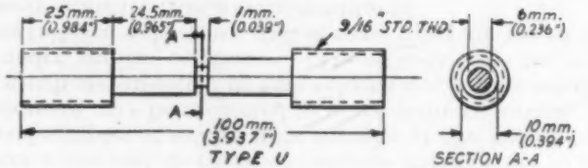


Fig. 58—Methods of Removing Impact Specimens from a Sample Welded Joint



PERMISSIBLE VARIATIONS:
CROSS-SECTION DIMENSIONS ± 0.025mm. (0.001")
LENGTH OF SPECIMEN..... ± 0.25mm. (0.010")
[illegible] OF NOTCH..... ± 1°

Cantilever and Simple Beam Test Specimens



Tension-Impact Test Specimens.

Fig. 59—Typical Impact Specimens

ing compressed air (pneumatic test) or water pressure (hydrostatic test). Ordinarily air is used only for relatively low-pressure testing (not over 50 lb.) because of the explosive character of the container when so charged.

In hydrostatic testing the pressure used is usually the design working pressure plus a certain additional percentage in excess of what would be expected in service. Sometimes a hammer test is applied while the container is subjected to the prescribed test pressure. Visual inspection is employed to determine whether leakage occurs at or below the test pressure.

Examples of closed containers which may be proof tested by internal pressure are underground storage tanks for liquids and pressure vessels of various sorts, such as oil-cracking stills and containers for compressed gases.

Open Containers.—Open containers may be tested hydrostatically (by filling with water) and visually examined for leakage. Examples are water or oil storage tanks or containers for other liquids. Watertight bodies for amphibious vehicles are usually tested by running the vehicle fully loaded into water, so that the vehicle floats, and examining the seams for leakage.

Structural Weldments.—Weldments, or parts thereof, which are designed as structural members to carry certain loads in service may be proof tested by setting up and loading in a testing machine or, as is sometimes done with large members, the weldment is set up and inertly loaded (sand bags or scrap iron) to determine whether calculated deflections are obtained at a prescribed load. Usually, loading in excess of that expected in service is applied to determine whether any part of the weldment acquires any permanent set or deformation.

EDITORIAL NOTE

In the Printed Book there is also included Section XII, Inspection Methods, and Appendix A, Definition of Welding Terms.

Investigation of Arc Starting Characteristics of D.-C. Welders with Reference to Electrode Freezing*

By Joseph M. Tyrner†

Synopsis

A METHOD for investigating the starting characteristics of an arc in d.-c. arc welding was developed and equipment was designed and built to simulate the behavior of an operator in starting such an arc. This testing equipment was used to compare the arc-striking ability and the arc-freezing tendency of an electrode when used with various type welding generators.

It was found that the determining factor is the electrode contact duration, that is, the time during which the operator leaves electrode and work in contact when he attempts to start an arc. Generators, to be satisfactory, should permit at least 40 millisec. contact duration.

Where the permissible contact duration between work and electrode is less than 40 millisec., only experienced welders are able to start an arc. Less trained men freeze the electrode to the work piece in a large percentage of their attempts.

Five generators of different designs were tested with the apparatus. Oscillograms of the current surge during the contact period were taken and the freezing point marked on the curves. It was found that the location of the freezing point depends on the shape of the current surge.

Characteristics of a welding generator as developed in these tests which yield good striking and non-freezing results are not contradictory to good general welding characteristics.

* A paper recommended by the A.I.E.E. Committee on Electric Welding for presentation at the A.I.E.E. winter convention, New York, N.Y., January 21–25, 1946. Reprinted from *Electrical Engineering*, March 1946.

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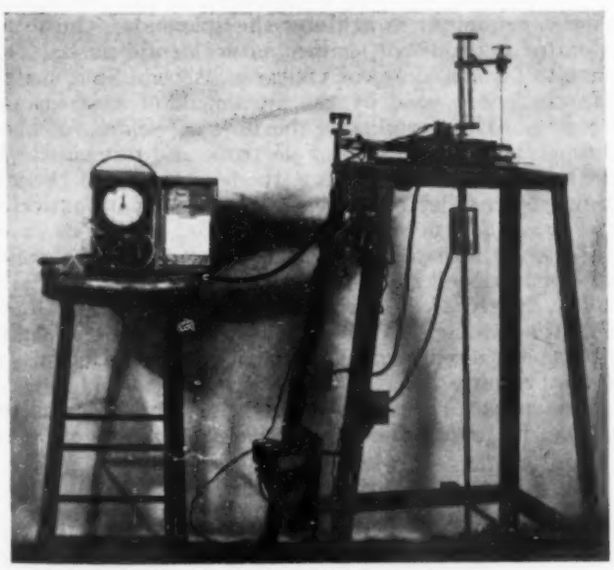


Fig. 1—Apparatus with Cycle Counter

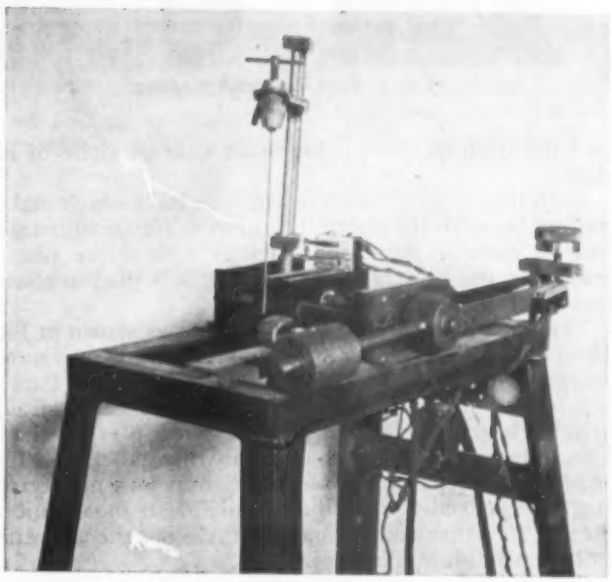


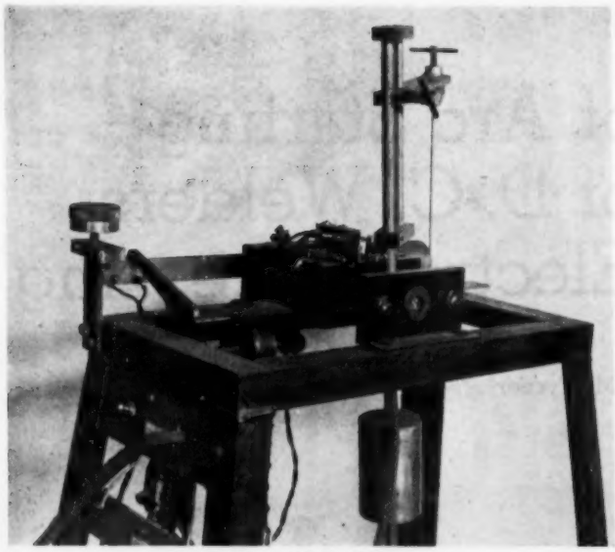
Fig. 2—Front View of Apparatus

Apparatus

Success in starting an arc using power from a d.-c. welding generator does not depend on the electrical circuit alone, but also to a great extent on the skill of the operator. An experienced man has fewer failures than an untrained one. If we want to design an apparatus with something like "adjustable operator skill" we have to analyze the skill of a welder. We find that operators when striking an arc may differ (1) in the contact pressure they exert, and (2) in the time they leave the electrode in contact with the work.

So far as the contact pressure is concerned, it is reasonable to assume that every operator tries to keep the contact pressure as low as possible in order to avoid freezing.

On the other hand, the aptitude of the man determines the duration of the contact between electrode and work piece. Therefore, it seems justifiable to accept this con-



F.g. 3—Rear View of Apparatus

tact duration as the predominant characteristic of his skill.

With this in view, an apparatus was built which makes contact between the electrode and work for an adjustable and measurable duration. Figures 1 to 3 are photographs of the apparatus. Figure 4 is a diagrammatic picture of it.

The apparatus consists of three parts as shown in Fig. 4 and numbered *1*, *2* and *3*. These three parts may move independently around the common axis *A–A*. Part *1* is a pendulum, on the upper extension of which an adjustable bracket *5* together with a chuck *6* is provided. The test electrode *7* is clamped in this chuck *6*. The pendulum is kept in a raised position as long as electromagnet *8* is excited to hold armature *9*. If the circuit of the coil *10* is opened, the magnet *8* releases the armature and the pendulum is free to swing.

Part *2* is the support of the work piece *11*, which is used for the freezing test with the electrode *7*. Weight *12* on Part *2* tends to turn it counter-clockwise, but *2* is held in approximately horizontal position by the bracket *13*, which rests on *3*.

The position of Part *3* may be adjusted by stop *15*, against which it is held by weight *14*. In this way, stop *15* establishes not only the position of *3* but, by means of bracket *13*, the position of *2* as well.

When pendulum *1* swings in a clockwise direction, the electrode *7* eventually reaches test piece *11* and makes contact. The impact of the electrode *7*, striking against test piece *11*, moves *2* clockwise, lifting bracket *13* from *2*. Electrode and test piece stay in contact until, on the return swing, bracket *13* touches *3* again. This stops *2* and electrode and test piece become separated. In this way, the position of *3*, adjusted by stop *15*, determines the length of the contact duration. If electrode *7* freezes to the test piece *11*, support *2* must follow, even after bracket *13* reaches *3*. In this case, *3* is pushed from stop *15* and weight *14* is lifted.

It is obvious that weight *12* controls the contact pressure of electrode and test piece while the force which tends to separate electrode and test piece is determined by weight *14*.

Contact pressure and break-away force were not varied during the experiments. They were adjusted to conditions comparable to actual welding as performed by an experienced operator.

The contact duration is measured by the cycle counter *16*. If the switch is in its "up" position, an a.-c. circuit through the cycle counter is closed as long as electrode and test piece are in contact. Swings of the pendulum with the switch in its upper position are used to adjust the contact time by setting stop *15*. The operator is protected from electric shock by the limit switch *18*, which keeps the a.-c. voltage from the electrode-test piece gap, so long as the pendulum is held by the electromagnet *8*.

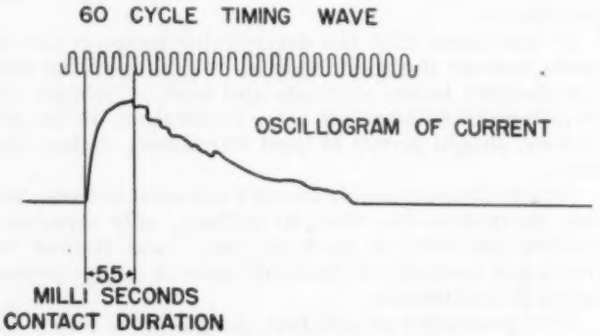


Fig. 5—Oscillogram of Current

The actual freezing test is made by putting switch *17* into its "down" position. This removes the a.-c. voltage from the electrode-test piece gap and applies it to the holding coil *19* of contactor *20*, which connects the generator being investigated to the apparatus. Switch *18*, in this case, prevents energization of the coil as long as the pendulum is held by the solenoid. Thus, the operator is protected against an accidental flash. The circuit of the holding coil contains a second limit switch *25*, which is opened by the movement of *3* in case of freezing. This terminates the flow of welding current through the short circuit of electrode and test piece. If the electrode does not freeze, the lengthening of the arc drawn by the electrode breaks the circuit automatically and no switch is necessary.

Tests are initiated with push button *24* which breaks the circuit of coil *10* of the electromagnet *8*.

The coil *10* of electromagnet *8* is energized by d. c. from the welding generator. It was found that the slight vibrations caused by an a.-c. magnet at that place falsify the test results.

The contact duration during the freezing test can be checked by taking an oscillogram as shown in Fig. 5.

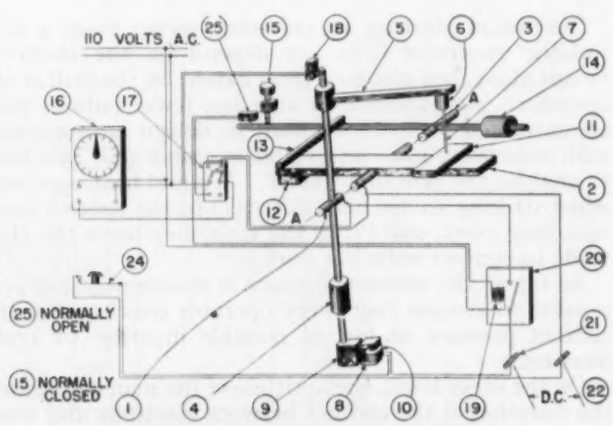


Fig. 4—Diagrammatic Picture of Apparatus

Procedure of Test

The operator clamps an electrode in the chuck *6* and provides a proper test piece *11*. He adjusts the elec-

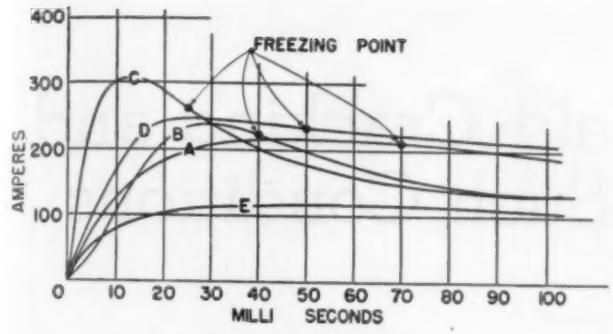


Fig. 6—Threshold Values of Contact Time

trode roughly by moving the sleeve of bracket *5* on the pendulum. The switch *17* is put into its "up" position. Button *24* is pressed and the pendulum released. The contact time is observed on the cycle counter. Then stop *15* is adjusted to bring the contact time nearer to the desired value and the test repeated. After several trials, the apparatus is ready for test. To increase accuracy three timing swings are made without resetting the counter to zero. The reading thus becomes the sum of three contact times and one-third of this value is considered to be the average contact time for the actual striking test. After the apparatus is adjusted to the desired contact time, switch *17* is put into its "down" position for the application of welding power. The next swing produces either a flash or the electrode freezes to the test piece.

A series of tests for different contact durations is run with a fairly large number of tests for each setting. For each setting, a number of freezings and a number of flashes are obtained. The frequency of freezings is calculated and plotted as a function of the contact duration. A curve is thus obtained which moves from a low percentage of freezings, at short durations, to a high percentage at long durations. The change from the low percentage to the high percentage is sudden. The contact duration yielding an equal number of freezings and flashes is arbitrarily called the "freezing time" of the generator.

Influence of Circuit Setting, Electrode Size and Electrode Coating

It can be shown theoretically that the curve of the surge does not change much with different current settings. Therefore, the freezing time also does not change. The electrode size has no influence because the contact in the testing apparatus is a point contact only, and it does not matter whether the contact-making point is on a $^1/_{16}$-in. diameter or on a $^1/_8$-in. diameter electrode.

The coating has no influence provided the coating is kept away from the point of contact.

Consequently, it was decided to make all tests with bare electrodes of $^3/_{32}$ in. diameter with generator settings of about 70 amp. welding current.

A few tests were made with other settings and with electrodes of other sizes and with different coatings. They confirmed these conclusions.

In order to eliminate the influence of scale, electrodes were ground square and test pieces cleaned thoroughly.

Generator Tests

Four commercial and one experimental generators with different circuits, but all of the same rating, were tested. All generators were set for the same welding output. The test results are shown in Table 1.

Table 1

Generator Tested	Critical Contact Time in Millisec.
A	70
B	40
C (Generator B without external reactor)	25
D	50
E (Experimental)	1000

In order to correlate these tests with the properties of the different electric circuits, open circuit short circuit transients of these five generators were determined by taking oscillograms. The freezing times are marked on the current curves, which are shown in Fig. 6. These curves show that freezing occurs some time after the highest point of the surge. The explanation may be that, during the decline of the surge, not enough heat is furnished to keep in a molten state the metal which melted at the height of the surge. The conclusion would be that the generator should reach its maximum current as late as possible. This is corroborated by the curve of generator *E* which approaches the maximum short circuit extremely slowly. Tests show that this generator practically never freezes.

Operator Requirements

The requirements of the operator were determined by watching the reaction of different men to the generators which had been tested.

It was found that the average operator is satisfied with a generator which does not freeze during the first 40 millisec. Generators with contact times as long as 70 millisec. are very good. Everything beyond that is excellent.

Simplified Tests

An apparatus of the kind described here usually is not available and it would be advantageous to be able to use standard equipment to judge a generator for its starting properties. Fortunately, an oscillogram of an open circuit short circuit test yields sufficient information. The curves of Fig. 6 show that the critical time is approximately twice the time the generator needs to reach the crest of the surge. If we accept this without trying to find any reason for it, we may say that a generator should take at least 20 millisec. to reach the crest of the surge. If it takes less, the generator is difficult to handle. On the other hand, a longer time indicates a generator with improved starting properties.

Acknowledgments

The author acknowledges and appreciates the cooperation given by J. J. Crowe, Assistant Vice-President, and E. E. Tisza of the Apparatus Research Department of Air Reduction Sales Co., and the able assistance of E. H. Cushman of the same company, who built the apparatus and ran the tests covered by this paper.

Acknowledgment is also made of the encouragement given to this investigation by C. I. MacGuffie, R. F. Wyer and R. C. Freeman.

Factors Affecting Weld Cracking and How to Overcome Such Conditions

By L. K. Stringham*

WHILE those familiar with metal working know that most metals can be arc welded the economy and degree of satisfactory welding results depend to a large extent on the quality of the weld itself. For example, there are certain conditions under which weld cracking may occur on mild steel but which can be overcome if careful consideration is immediately given the factors that are known to cause such defects.

These factors may be listed as (1) analysis of parent metal; (2) bead shape; (3) welding current; (4) type of electrode; (5) rigidity of joint. Usually weld cracking is due to one or a combination of these causes.

Since it is generally known that rigidity of a joint can usually be eliminated by redesign or by developing a welding sequence that leaves the ends of the joints free to move as long as possible, the first four factors only will receive special consideration in this discussion.

As the analysis of plate (parent metal) is of course, beyond control, the prime factors to consider if cracking is to be overcome is proper bead shape, correct current, proper type of electrode or a combination of these three.

In order to illustrate the effect of bead shape and welding current, the following three different analysis steels are used as examples:

	Steel A	Steel B	Steel C
Carbon	0.15	0.31	0.35
Silicon	0.066	0.08	0.29
Sulphur	0.030	0.026	0.031
Phosphorus	0.015	0.015	0.04
Manganese	0.48	0.65	0.80

Steel A.—The analysis of Steel A is such that weld cracking is extremely unlikely as indicated in Figs. 1, 2 and 3 showing fillet weld cross-sectional views. In this case welding techniques were varied from (Fig. 1, very concave bead) slight weave and holding long arc; (Fig. 2, flat bead) applying stringer bead and holding short arc; (Fig. 3, convex bead) dragging the electrode. In this case, the use of relatively high current, 350 amp., was permissible, the bead shape being unimportant, as there were no cracks.

Steel B.—The analysis of this steel containing 31% carbon, indicated that cracking was apt to occur unless the proper welding procedure was used. Thus, by using the same current (350 amp.) and the same techniques we find that cracks occurred in the concave and flat weld beads (Figs. 4 and 5) but were overcome by dragging the electrode to produce a slightly convex bead shape (Fig. 6). The concave bead in which a weaving technique with a long arc was held produced a badly cracked weld bead. The technique of applying a stringer bead with short arc produced intermittent cracks, and the dragging technique resulted in no cracks.

Steel C.—This steel whose analysis showed 0.35 carbon and 0.29 silicon was very susceptible to cracking and the condition could not be eliminated with current at 350 amp. despite the best obtainable bead shape. It was therefore necessary in this case to lower the welding current and at the same time maintain a slightly convex bead shape. Resulting examples were as follows: Fig. 7, dragging technique with current at 350 amp. produced a convex bead with weld badly cracked; Fig. 8, the same dragging technique with amperage reduced to 300 also resulted in a convex bead but with no cracks; Fig. 9, a weaving technique holding long arc at 300 amperage produced a concave bead with weld badly cracked. This latter example (Fig. 9) illustrates the necessity for maintaining the correct bead shape even at lower current when the steel plate is susceptible to cracking.

In the foregoing examples it will be noted that slightly convex beads are less apt to crack than flat or concave shapes. But since the type of electrode has considerable influence on bead shapes, it is therefore desirable to select electrode types which will produce a convex shape. In this connection shielded-arc electrodes conforming to AMERICAN WELDING SOCIETY specifications E-6012 have a distinct advantage over other types of mild steel electrodes when welding in the flat or horizontal fillet position as may be seen by the comparison of weld cross sections made with A.W.S. E-6012–E-6013 rod used as an example.

Figure 10 shows the normal bead shape and Fig. 11 the best obtainable bead shape from the standpoint of cracking made with this particular E-6013 electrode in $\frac{1}{4}$-in. size.

Figure 6 also shows the normal bead shape made with the formerly mentioned A.W.S. E-6012 electrode in which the desirable, convex shape, for crack elimination is obtained.

In summarizing, we find that if plate analysis can be kept within the preferred limits as outlined in the following table, weld cracking is very unlikely to occur and almost any desirable bead shape, type of electrode or current may be used providing the joint is not too rigid.

Limits of Steel Analysis for High-Speed Welding

	Low, %	Preferred, %	High, %
Carbon	0.10	0.13–0.20	0.25
Manganese	0.30	0.40–0.60	0.90
Silicon	..	0.10 or under	0.15 max.
Sulphur	..	0.035 or under	0.05 max.
Phosphorus	..	0.04 or under	0.04 max.

Even when a joint is not extremely rigid, if plate analysis limits are exceeded, the bead shape, type of electrode and welding current become important.

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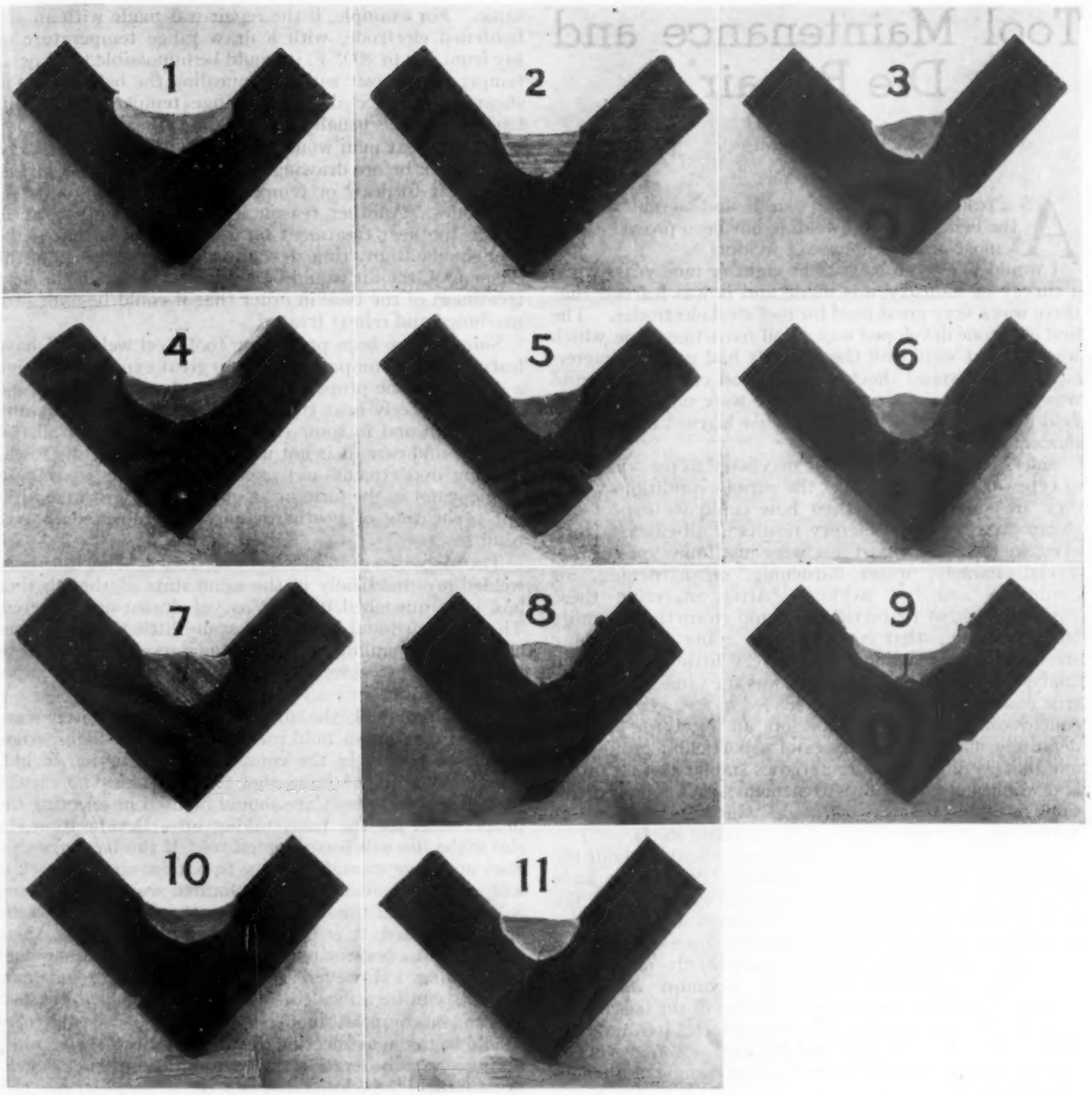

Fig. 1—Very Concave Fillet Weld Bead, Without Cracks, Using 350 Amp. with Slight Weave and Long Arc (Steel A)
Fig. 2—Flat Stringer Bead, Without Cracks, Using 350 Amp. and Short Arc (Steel A)
Fig. 3—Convex Bead Without Cracks, Using 350 Amp. and Dragging Electrode (Steel A)
Fig. 4—Concave Fillet Weld Bead, Badly Cracked, Using 350 Amp., Weaving Technique, Long Arc (Steel B)
Fig. 5—Flat Bead, Intermittent Cracks, Using 350 Amp., Stringer Bead, Short Arc (Steel B)
Fig. 6—Convex Bead, No Cracks, Using 350 Amp. Dragging Electrode (Steel B)
Fig. 7—Convex Fillet Weld Bead, Badly Cracked, Using 350 Amp., Dragging Electrode (Steel C)
Fig. 8—Convex Bead, No Cracks, Using 300 Amp., Dragging Electrode (Steel C)
Fig. 9—Concave Bead, Badly Cracked, Using 300 Amp., Weaving Technique with Long Arc (Steel C)
Fig. 10—Normal Bead Made with A.W.S. E-6013 Shielded-Arc Electrode, $^1/_4$-In. Size
Fig. 11—Best Obtainable Bead Shape Made with A.W.S. E-6013 Electrode, $^1/_4$-In. Size

If the best-shaped bead obtainable at a given welding current does not overcome weld cracking, it is necessary to either reduce the current or change to an electrode type which will produce a more convex bead.

Tilting the work from 5 to 15° and welding uphill will tend to form a more desirable convex bead (excessive convexity is not necessary).

Decreasing the welding current helps achieve the desired results by reducing the admixture (parent metal and weld metal) and actually tends to produce a more convex bead.

Although flat position fillet welds are used to illustrate this article, the same principles apply to all fillet and butt welds in any position.

Tool Maintenance and Die Repair*

By P. D. Scott†

As a result of years of research and actual tests in the field, tool steel welding has been proved to be a most practical phase of welding.

I would like to go back some eight or nine years when a survey of industry was made and it was learned that there was a very great need for tool steel electrodes. The first electrode developed was an oil-hardening type which was thought would fill the bill. It had good characteristics to withstand shock, hold a good cutting edge and was fairly abrasion resistant. We were not long in the field with this one electrode when we learned it was quite inadequate to fill the bill.

Since manufacturers find it necessary to use a number of types of tool steel to meet the various conditions which dies are subjected to, then how could we expect one electrode to give satisfactory results in all cases. However, we did learn that there were just four types of tool steels; namely, water hardening, oil hardening, air hardening and hot working. After analyzing these various types, we found that we could group them in quite large numbers; that is, there were many oil-hardening steels for example that showed very little difference in analyses but the heat treatment was the same. This was true in all the other types. This led us to a very definite conclusion. We would develop an electrode not to definitely match the analyses of a particular group, but one that would give characteristics similar to that group and would match the heat treatment. We followed this same idea all the way through, which included water hardening, air hardening and hot-working steels.

There is nothing mysterious nor complicated about the application of tool steel electrodes. Procedures have been set up and I believe that any one who will take the time to read and follow these procedures will experience no difficulty in doing this type of work successfully.

Results will depend on pretreatment of the job such as preheating temperature employed, technique employed during the welding sequence, admixture of the base metal with the deposit which will influence the hardness as-welded or as heat treated and the rate of cooling as the mass of the object being welded acts as cooling or quenching medium.

A great many people are confused by the difference between tool steel welding and hard facing. They are definitely not synonymous. Hard-facing materials were originally developed to lay down deposits that would withstand abrasion; whereas the deposits of tool steel electrodes even though they are hard as welded are just as flexible, just as heat treatable and just as workable as any tool steel any heat-treat man has ever worked with.

We learned, too, that heat treatment was of utmost importance. Let us take, for example, an oil-hardened shear blade that is chipped or spauled out. After repair has been made by welding, how could you expect to draw or temper the deposit unless the heat treatment was the same. For example, if the repair was made with an air-hardened electrode, with a draw range temperature of say from 700 to 900° F. it would be impossible to draw or temper the deposit without annealing the balance of the shear blade since the draw range temperature of oil-hardening steels usually is from 300 to 400° F.

A heat-treat man would not think of putting a tool or die to work before drawing or tempering and it is just as important to draw or temper the deposits of tool steel electrodes. Another reason why it is so important to match the heat treatment on a die or tool is that if the user should at any time desire to change the design of the die or tool, then it would be necessary to match the heat treatment of the base in order that it could be annealed, machined and reheat treated.

Since I have been promoting tool steel welding I have learned that a company will go to great expense to design a die, select the proper tool steel and use the most rigid care to properly heat treat it. The die then is put into production and in some cases fails. Now, after all this expense and care, it is not unusual to rush the die to the welding department and expect the welder to wave a magic wand in the form of an electrode over it and without preheating or posthardening it is expected to give results.

The deposits of tool steel electrodes being hard as-welded are practically in the same state as though they had been quenched but not as yet drawn or tempered. They are hard and brittle and stand little shock without chipping or spauling. It is just as important to draw or temper a tool steel weld deposit as it is to draw or temper the original die.

When practical, die units can be compositely constructed by using a mild medium-carbon or high-carbon steel as a base. In the composite construction of hot-working dies an S.A.E. steel of the nickel-chrome variety should be selected. Care should be used in selecting the proper steel for the base, taking into consideration the shock the die will be subjected to. If the base material does not have enough rigidity to withstand the shock it will collapse underneath the harder weld deposit and will fail. Since the deposits of tool steel electrodes are hard as-welded, it is not necessary to heat treat them other than to draw or temper if the units lend themselves to grinding. However, if it is necessary to machine, deposits can be annealed, machined and reheat treated.

Also, in composite construction of tools or dies care should be taken in selecting the proper tool steel electrode, taking into consideration the heat, abrasion, shock, thickness of metal to be formed or cut, etc.

Another phase of tool steel welding which many manufacturers are taking advantage of is in the correction of design. In many cases after dies have been put into production it is necessary to make changes in radii or contour; also, to rectify errors such as where dies have been mismachined. These changes or mistakes can very readily be corrected by welding with electrodes having characteristics similar to that particular type of steel and matching the heat treatment.

It has been a long hard educational program to promote this phase of welding but today it is being accepted as a most practical practice. Thousands of manufacturers are taking advantage of the vast savings accorded by tool steel welding. It has helped them to save material, save man-hours and minimize production delay.

* Presented before Nov. 27, 1945, Meeting, Louisville Section, A.W.S.
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Creation of a Shipyard for Welded Construction*

By R. F. Grambow†

WITHOUT doubt the record of the shipbuilding industry during the recent war was outstanding. This is especially noteworthy in view of the fact that a large percentage of the vessels were constructed in yards especially built for wartime production, and in many cases operated by newcomers to the industry. Marinship was one of many such yards; its basic story is doubtless applicable to numerous other emergency shipyards. However, we feel that some of the problems that arose, especially those concerning welding and welding inspection, and our solutions of them are worth passing on to others.

On March 2, 1942, the W. A. Bechtel Co., a western engineering and construction organization, was requested by the United States Maritime Commission to investigate the possibility of building and operating a shipyard for the construction of EC-2 cargo vessels. At the same time it was stipulated that in the event of the construction of such a yard, completed vessels would be expected before the end of that year.

One week later, after an intensive survey, a reply was sent back to Washington stating that the company was prepared to proceed immediately with the design and construction of either a six-way or a four-way yard. A proposed layout, accompanied by a preliminary cost estimate, was submitted at the same time. Two completed vessels were promised by the end of the year based upon a six-way program. The data submitted proved satisfactory and on March 12th Marinship became an approved project.

Several sites, all of which were in the San Francisco Bay area, had been considered during preliminary discussions. Sausalito, located six miles north of San Francisco on Richardson Bay in Marin County, was chosen because of its isolation from other defense industries, its uncongested housing conditions and its potential labor reserve. The site was adjacent to the Southern Pacific Railroad so that transportation of steel and heavy equipment was not a problem.

The layout (Fig. A) of the yard was governed primarily by space limitations. The proposed site consisted of approximately 100 acres of land, 900 ft. wide and about one mile long. The length of the yard paralleled the shoreline. The layout of buildings and shops was based on straight-line flow of material from the time of its arrival to the yard until it reached its final destination. At the northernmost end of the yard the Administration Building occupied a position immediately adjacent to the main highway. South of this point in the order mentioned were the Steel Yard, Plate Shop and Mold Loft, Subassembly Shop, skid and jig area, ways, outfitting docks and, immediately in front of the docks—the warehouse. Then, the Machine Shop, Pipe Shop, miscellaneous small shops, pipe storage area and machinery storage building.

Railroad spurs were run directly into the Steel Yard. Raw steel was transferred from the freight cars to the Steel Yard by truck crane. From the Steel Yard the plates and shapes were delivered either by hyster or trailer truck to the Plate Shop. From this point the fabricated steel went through the Subassembly Shop which was separated from the Plate Shop by a gantry way some 200 ft. wide. From Subassembly, the assembled sections were either transferred to the larger jig areas, or directly to the hulls. This principle of unidirectional flow was maintained as closely as possible with all materials. The location of the warehouse at the center of the south end of the yard was ideal since most of the material stored threre was delivered either directly to the hulls or to the Outfitting Shops.

The Plate Shop contained seven working bays, each approximately 60 x 250 ft. These were served by 11 bridge cranes and 28 jib cranes. The major mechanical equipment consisted of three plate bending rolls, the largest of which had a capacity of 32-ft x $^3/_4$-in. plate; three plate shears, the largest of which had a 10-ft. x $^1/_2$-in. plate capacity; two breaks; two 400-ton and one 300-ton hydraulic presses; several power punches and drill presses. All plate edge preparation was accomplished by oxyacetylene burning, the equipment for which consisted of three Travographs, two Planographs and one Oxygraph. One 3-ton, and one 8-ton welding positioner were provided. Two double-end oil furnaces were available to the bending slabs.

The Subassembly building contained six working bays approximately 70 x 225 ft. Steel was handled by 12 bridge cranes. The working level of the shop consisted of steel rails on 2-ft. centers raised 3′-0$^1/_2$″ above the floor.

The skid and jig area located south of the Subassembly Shop was served by four whirleys of which the maximum individual capacity was 60 tons. One special feature was the reinforced concrete jigs for the deckhouse assembly. These jigs were built to the exact camber of the deck and required a minimum amount of adjustment.

The six ways were each 556 x 82 ft.; end launching; $^1/_2$ in. per foot slope; cambered to a radius of 33,091 ft.

The location, elevation and design of the Outfitting Docks received considerable study and are worth special mention. In order to overcome the time lost by workmen descending from the deck of the vessel to the usual ground level docks and in order to facilitate material handling, the docks were elevated so that the roadway was level with the upper deck of the ship. This was about 32 ft. above the mean low water and about 20 ft

* Presented at a joint meeting of the New York Section of the Society of Naval Architects and Marine Engineers and the AMERICAN WELDING SOCIETY in New York City on Feb. 15, 1946.

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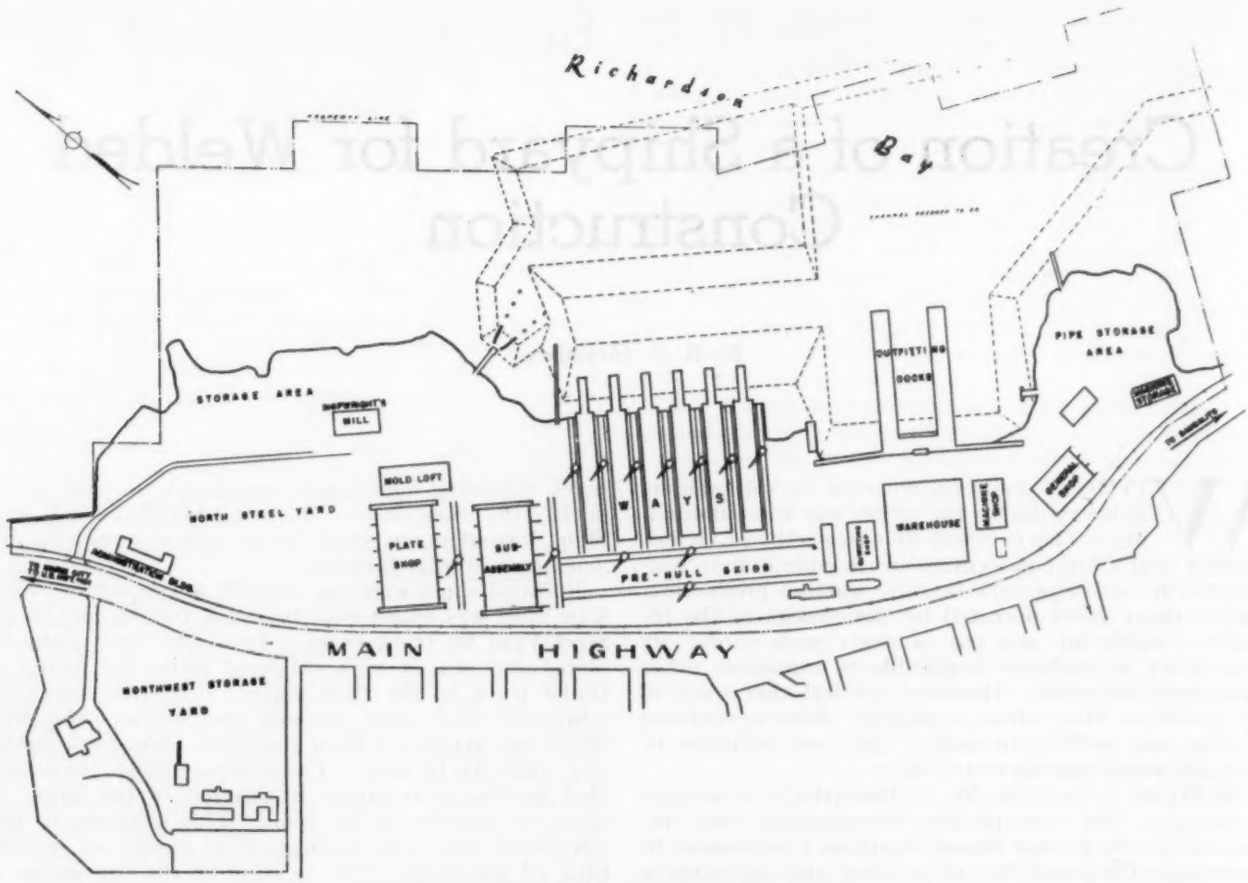


Fig. A—Yard Layout, Marinship Corp.

above the surrounding yard grade. The substructure of the dock consisted of spliced piles on 8-ft. centers, generally driven completely through the mud layer to firm rock. The upper section of the piles was creosoted. A typical wood column structure was constructed on the wood caps of the piles. Fender and dolphin piles were installed. Fender logs about 3 ft. in diameter were provided to hold the ship off. Ramps were constructed at the north and south ends of the docks so that trucks and other vehicles could travel directly to the upper deck level of the vessel. A mezzanine built under the upper deck of the docks was used for welding machines, storerooms, toilet facilities and locker rooms. Lifting equipment consisted of four 16-wheel truck cranes of 15-ton capacity, and several smaller 8- and 12-wheel truck cranes.

Actual construction of facilities was preceded by removal of some 40 residences which were located on the shipyard site. This operation was started on March 18, 1942, and completed on April 26. During this same period other abandoned facilities, principally those of the North Western Pacific Railroad shop, were dismantled and removed. The grading of the site started on Mar. 28, 1942; the removal of approximately 850,000 cu. yd. of dirt was completed on June 27, 1942.

Pile driving started Mar. 31, 1942, and was completed November 10, 1942, during which period some 30,000 piles had been placed. The actual pile driving for the ship ways began on May 20, 1942, and was completed for the first way on June 30, 1942, three days after the laying of the first keel. This neck-and-neck race between keel laying and pile driving continued through September 11th, at which time the sixth keel was laid. The way for that sixth keel was completed on September 18th, one week after keel laying. It might be mentioned that our hull surveyors had a lively time during this period. The first vessel was launched on September 26th and was towed to a rather uncompleted Outfitting Dock, only one finger of which had been completed. The extreme scarcity of piling and other lumber at this particular time made it very difficult to provide outfitting space as the first four ships left the ways. The actual driving of the outfitting dock pilings was not completed until November 10th by which time the two vessels had been launched. The framing was completed concurrently with the launching of the fifth vessel.

In spite of construction difficulties, due chiefly to material shortages, Marinship's original promise to the Commission was exceeded by three vessels; by the close of the day, Dec. 31, 1942, five EC-2's had been delivered to the United States Maritime Commission.

Long before any of us had really been able to settle down to a stabilized shipbuilding program, the Maritime Commission asked Marinship to take on the much tougher job of tanker construction. This happened in September of 1942. Plans were not available until the middle of October, when a complete set of tracings for the 6000-hp. T2-SE-A1 Tankers designed at Sun Shipbuilding and Dry Dock Co. was forwarded to our yard. With this information as a basis for design, new plans were developed to accommodate a 10,000-hp. turbo-electric main propulsion unit, which at that time the General Electric Co. could supply in quantity. As the result of a very intense design program, Marinship was able to lay the first keel for this class of vessels on Dec. 7, 1942.

During the following period Marinship delivered a total of 77 tankers. The original EC-2 program was curtailed in view of tanker production. A total of 15 of the Liberty ships was completed by June of 1943.

The climax of tanker production was reached in June of 1945, when our 86th hull, the SS *Huntington Hills*, was delivered 33 days after keel laying and 30 days ahead of the contract delivery day. We were especially pleased with this record in view of the fact that this same vessel required only 520,000 man-hours for completion, the least number of man-hours for any of the T2-SE-A1 Tankers built at our yard.

The Marinship organization consisted of three divisions: Production, Administration and Engineering. The heads of these divisions along with the General Manager and the President comprised the Operating Committee. This group set the yard policy and decided all major in-yard issues.

The Engineering Department was guided by two fundamental concepts. The first of these was based upon the initial function of issuing the original plans and specifications at the outset of the shipbuilding program during this period the Engineering Department was more or less the fountainhead of information and the rate of dissemination of this information determined to a great extent the rate of progress of vessel construction. The second concept was based on continued repetitious construction, after the original issue of plans and specifications had been completed. In this phase of operation the Engineering Department considered that it existed strictly as a service organization at the disposal of the Production Department. The realization of this principle at Marinship was responsible for many simplifications and improvements in design which were initiated by the men in the yard, especially in connection with modifications to improve welding sequence and welded joint design.

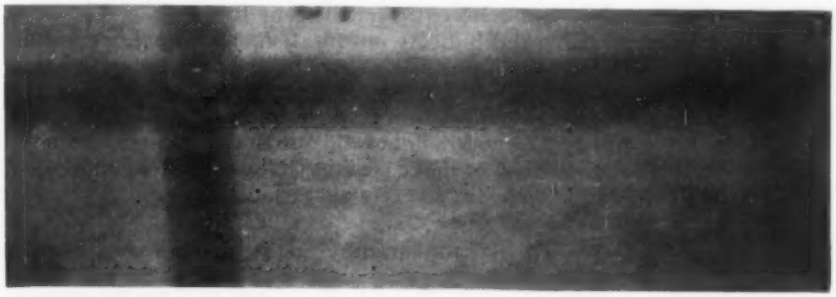


Fig. 1

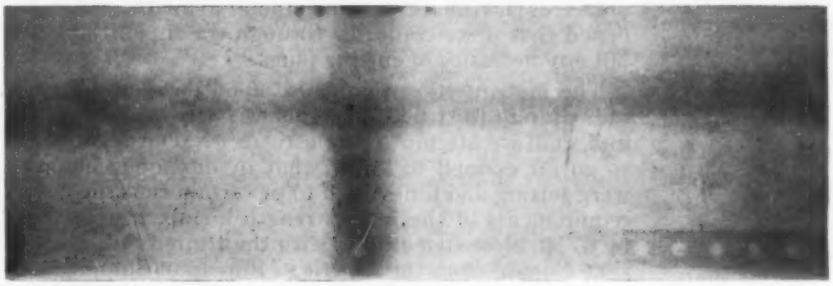


Fig. 2

Fig. 3

Fig. 4

In establishing this relationship between Production and Engineering it was realized that some clearing house had to be set up within the Production Department to consider the various suggestions arising on the ways and in the shops, and to study the over-all effect of such suggestions upon the entire production picture. This was accomplished by the formation in the Production Department of what we called the "Works Standards Division" under the direction of our welding engineer. It was the function of this group to study all suggested improvements from a practical over-all yard standpoint and to submit worthy suggestions to the Engineering Department for action. This, of course, eliminated the necessity for the engineers to spend excessive time developing ideas which would later prove to be impracticable or detrimental to the over-all program. A counter group of engineers was set up to study the practical suggestions as approved by the Works Standards Division to determine if the ideas were technically sound. Upon Engineering approval, plans were altered to comply with the requested change or modification. This procedure was developed so that urgent changes received immediate attention and revised plans were often distributed a few hours after a specific problem arose. This type of service allowed the engineer to expect very rigid control over design by minimizing the tendency of the workers to take design matters into their own hands.

The Works Standards Division had the added responsibility of monitoring the fabrication and erection of the hull to insure that plans and specifications were being followed. When such was not the case they determined whether the design or the man on the job was at fault, and then, depending upon their findings, either the plans were changed or the procedure was altered. In no case was an unsatisfactory condition allowed

to prevail on future hulls. Corrective action was always taken.

A Naval Architect's prime concern regarding welding is the assurance that the completed hull structure conforms to his specification and that each joint is performing its function and is capable of developing its calculated stress without failure and with the proper factor of safety. In order to achieve this end he must first design the hull in such a manner as to facilitate assembly, to eliminate the necessity of excessive field plate edge preparation, to eliminate potential notch conditions, to eliminate inaccessible welds and to minimize overhead welding, to eliminate doubler plates, etc.

With this accomplished, the next step is to establish rigid welding control in order to insure that the design is adhered to and that the prescribed welding procedures and sequences are followed. The final assurance of the success of this control then rests in the proper inspection of the completed weld.

At Marinship our first step was to carefully scrutinize the contract plans with the thought in mind of standardizing weld bevels, eliminating staggered butts, eliminating notch conditions in the main strength members (especially the sheer strake), removal of all attachments or miscellaneous foundations and outfitting items from the sheer strake, and in general simplifying awkward and troublesome welding details. In cooperation with the Welding Division, the Engineering Department developed approximately 30 typical standard welding details which were chosen to include every possible type of weld on the hull. By following this system it was not necessary to detail the welds on any of the structural plans; instead, a particular joint would be identified by the number of the standard weld bevel which would apply. To facilitate operations in the shops, and to eliminate the necessity for constant reference to the design drawings, a cutting sketch was made for all flat rectangular plates and straight shapes. This cutting sketch indicated cutting dimensions, bevels, excess stock and piece mark. In cases where the plates or shapes had shape, templates were provided bearing this same type of information. Following this same practice of giving selective information to the shops, individual shop assembly drawings were developed. After the completion of such plans they were turned over to the Welding Division to determine a sequence of welding. It was after this step that actual work on the steel began. A weld layout group would then actually mark this combined information on the steel for the guidance of burners and welders. In this manner a relatively rigid control was attained. No burning or welding could be done until the weld layout man, who came under the supervision of the welding engineer, had transferred the engineering information and the welding sequence from the plans to the steel.

These precautions, although rather far reaching, were of little value without proper classification of the welder himself. We all realize that although a welder may complete a very satisfactory job on a down-hand butt weld, he may fail on an overhead butt or a vertical weld. In view of this factor Marinship took special precautions to go further into welder classifications than required by the American Bureau of Shipping and the United States Coast Guard and actually classified each welder for a specific type of job.

Regardless of the ambitious control program that was attempted, we realized that because of lack of sufficient and proper supervision because of the intense pressure of the wartime program, we still could not be sure of the finished product. Frequent visits to the yard uncovered many deviations and variations from our planned way of doing things. We realized that the final analysis rested in proper and adequate welding inspection. This inspection fell into three categories: visual, physical and radiographic.

At the beginning of our program we relied chiefly on the first two of these. Visual inspection covered such things as undercutting, overwelding, pitting, unsatisfactory reinforcement, saddle welds, etc. Physical inspection included test coupons, trepanning and, in some cases, chipping. The men on the ways were naturally seeking some way of eliminating trepanning and in this respect they had the full sympathy of both the welding engineer and the Engineering Department. It was felt that plug cutting was unsatisfactory and, in fact, bad practice. Welding the hole, we felt, did nothing but set up further stresses in a structure already stressed some incalculable amount. We realize that although the plug was a true sample for one particular spot, the weld 1 ft. away could be entirely different in nature; further, if the plug did indicate an unsatisfactory weld, we had no way of knowing the extent of the unsatisfactory weld without cutting further plugs, or chipping. In such cases we would set out on a chipping expedition, chipping until we came to sound weld and in many cases then chipping further to make certain that sound weld continued, all of which was a costly operation and in many cases an unnecessary one.

We felt that radiography might be the answer and we embarked upon a program of experimentation. To this end the services of the Industrial X-Ray Engineers were obtained. This organization had successfully applied radiography in other west coast yards and we considered ourselves fortunate to find them available. We believed that if we could see through the metal there was not any necessity of cutting plugs.

The first question that arose upon deciding to apply radiography to structural welds was, "How much of the hull shall we attempt to investigate?" Our answer was to go far enough to know what quality of welding we were getting and far enough to be certain that the design requirements of the main strength members were being met. In close cooperation with the United States Maritime Commission, the American Bureau of Shipping and the United States Coast Guard, the Marinship Welding Division and the Engineering Department agreed upon which portions of the structure were to be included in the so-called vital area. This area centered around the midship half length, where stresses were known to be a maximum, but also included certain welds at the forward and after portions of the vessel. Within this zone a basic group of approximately 50 butt welds were chosen to be radiographed.

Both X-rays and gamma rays were used. Gammagraphs were preferred because of the relatively simple and compact equipment, the absence of the need for elaborate preparations and the over-all speed of operation. X-ray was comparatively bulky (crane facilities were required for handling it); it was often difficult to support the tube head properly, and the over-all operation required more man-hours than radium. In either case similar safety precautionary measures were necessary. The Industrial X-Ray Engineers followed their established rules for the safe handling of their equipment and the shipyard provided guards to divert the workers from the area being inspected.

Each negative was marked to indicate the frame, plate and strake so that it could be readily correlated with the shell expansion or deck plating plan. A lead arrow was placed alongside the weld to indicate the forward end. A 9-hole penetrameter of the step type, graduated in 0.010 in., was used. The penetrameter was placed on the radium side of the weld. With the use of fine-grain

films a perception of less than 2% of the thickness of the material was obtained.

In order for radiography to be at all useful it was realized that some set of standards must first be established and agreed upon by all agencies involved. Based upon the experience of the Industrial X-Ray Engineers, in combination with specific known conditions at Marinship, the following set of standards were adopted.

Each weld was to fall into one of four classifications:

1. *Faultless*—a weld showing no inclusions, undercutting, cracks or defects of any kind with adequate but not excessive reinforcement (see Fig. 1).

2. *Satisfactory*—a weld which did not reveal evidence of cracks, and which was free of linear defects of more than 1 in., slag inclusions, even though they were fairly dense (but were surrounded by several inches of good material), were allowed in this classification. Undercutting and other surface flaws did not affect this classification but were noted. In some cases it was necessary to check the welding procedure in order to properly identify markings that appeared to be defects (see Fig. 2).

3. *Substandard*—defects in excess of those coming in the "Satisfactory" classification but not of serious enough nature to be classed as "Unsatisfactory." However, if the defect occurred in an area where maximum joint efficiency was a requisite, this class of weld was called to the attention of the welding engineer and the inspection agencies to determine if repair of the weld was warranted (see Fig. 3).

4. *Unsatisfactory*—radiographs showing linear defects of over 4 in. on the film, especially those which extended through the end of the film. A chain of slag inclusions, porosity or pipes were considered the same as linear defects. Cracks of any kind required repair. However, care had to be exercised in differentiating between lack of fusion and an actual crack (see Fig. 4).

It should be noted that "Substandard" or "Unsatisfactory" welding was submitted to the welding engineer for two main purposes:

1. So that he could review the function of the particular weld as defined by the original engineering design and then determine if the joint as evaluated by the radiograph was acceptable or if it required repair, bearing in mind that in many cases the "cure" of the defect might result in a condition worse than the defect itself.
2. So that the "Substandard" and "Unsatisfactory" work could be discussed directly with the welding supervisors who were responsible for the quality of the joint, and who could in turn contact the welder who actually did the work.

There is one very necessary link that must be present in order to derive the maximum control offered by radiography. Some means must be provided so that the welder who made any particular weld can be identified. This was accomplished at Marinship by a very simple card system which allowed us to know *who* welded *what* on each hull. Each hull erection section was represented by a master card bearing the same identifying number as the section itself. Each of these master cards was supplemented by a secondary set of detailed cards which enumerated the various shipfitting and welding operations.* With such a system of weld identification any defect can be immediately traced to its source whether that source be plate edge preparation, welding technique or poor shipfitting.

With the widespread use of radiography we had positive knowledge that each welded joint was capable of developing its designed stress without failure. Furthermore, we knew the quality of the welding that was being performed in the various shops and on the ways, and we could readily investigate any relaxation of the high standards of workmanship that we had adopted. We no longer had to deal with opinions as to whether the workmanship was satisfactory; our pictures were indisputable. There was no argument against a picture—especially when (as happened from time to time) the unsatisfactory weld was chipped out in the presence of the welder and his superviser. The few nonbelievers soon learned that the film did not lie and that the only course to follow was that of careful workmanship and adherence to approved procedure.

In general the tendency was for the welders to improve the quality of their welding and to accept the evidence brought forth by the radiograph for what it was worth. Each welder realized that his work was subject to possible check. As a result he paid particular attention to plate-edge preparation, realizing that the quality of his work depended on the quality of the work done before him; this in turn tended to improve the shipfitting itself. Each craft concerned realized that in radiography the inspection forces knew at whom to point the finger.

Our confidence in the standards established and maintained has been verified by an enviable absence of structural failures upon any of the vessels built by Marinship. We attribute this primarily to:

1. Careful control of design, to make the best possible use of welding and to eliminate all carryovers from riveted construction that might create unsafe notch conditions and locked-up welding stresses.
2. Close cooperation between the various crafts and the welding engineers to insure that established procedures were followed.
3. The close cooperation between the various inspection agencies and the shipyard in establishing uniform standards of workmanship, especially in regard to radiography.
4. The immediate correction of all poor workmanship revealed by gammagraph and/or radiograph.

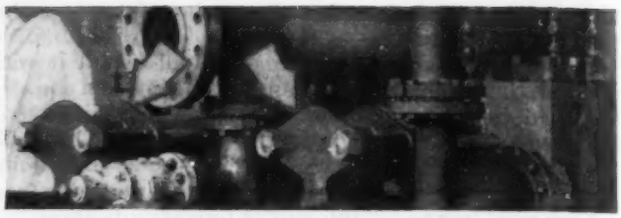
A more detailed description of the use of X-ray and gamma-ray in welding ships has been presented by Russel G. Rhoades, welding Engineer of Marinship Corp., in the May 1945 edition of the *Log*.

The story of Marinship's development of welding control was presented at the 25th annual meeting of the AMERICAN WELDING SOCIETY in October 1944 by D. G. Maxson in his paper "Controls Required for Safe and Economical Construction of Welded Ships." This paper was also printed in the December 1944 issue of THE WELDING JOURNAL.

Appreciation is expressed for the material regarding radiography made available to the author by Harold Hovland of the Industrial X-Ray Engineers, San Francisco, whose organization performed all radiography at Marinship Corp. and did a great deal to develop the standards described earlier in the paper.

* These cards are completely described in D. G. Maxson's paper presented at the Annual AMERICAN WELDING SOCIETY's meeting of October 1944.

Conversion of Cast Steel Plunger Crosshead to Welded Design



Welded Crossheads Installed on Pump

By J. R. Morrill*

TO obtain maximum economy through changeover to welded design, it is desirable to forget about the former part . . . to design for the functional requirements of the application, using welded steel. This is especially true when converting from cast iron to welded steel—a material with greater stiffness and strength. It also applies where conversion is from cast steel to welded steel—materials which have similar physical properties.

Ofttimes, however, the part is so simple, the dimensions are established and the function remains the same . . . making advisable more of a "direct replacement" approach and resulting in a welded part which very much resembles the former part.

This was the case in redesigning the plunger crosshead discussed here . . . formerly a cast steel part. This is one of a series changed over by The National Transit

* Assistant to the Vice-President, Lincoln Electric Co., Cleveland, Ohio.

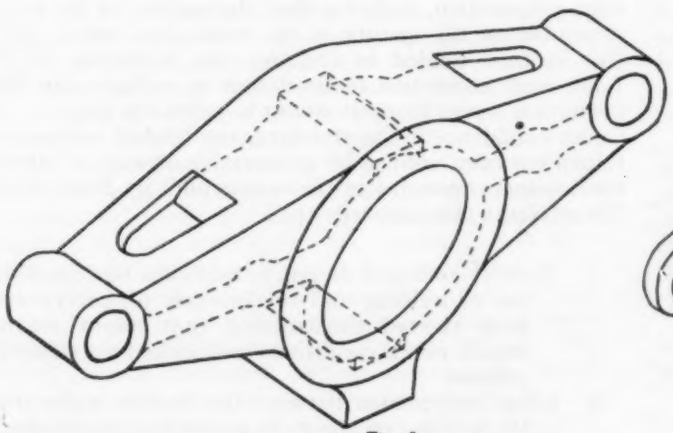


Fig. 1

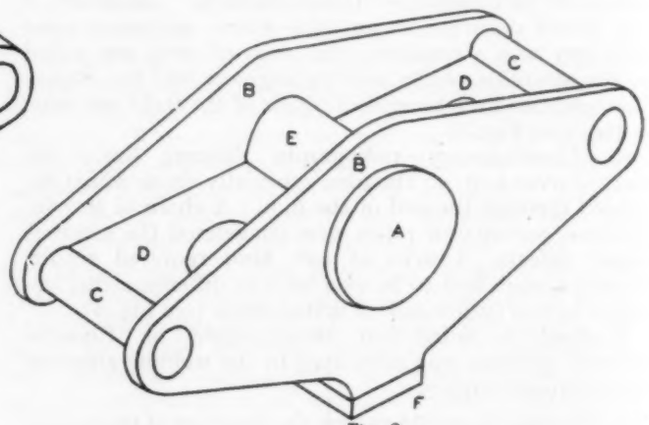


Fig. 2

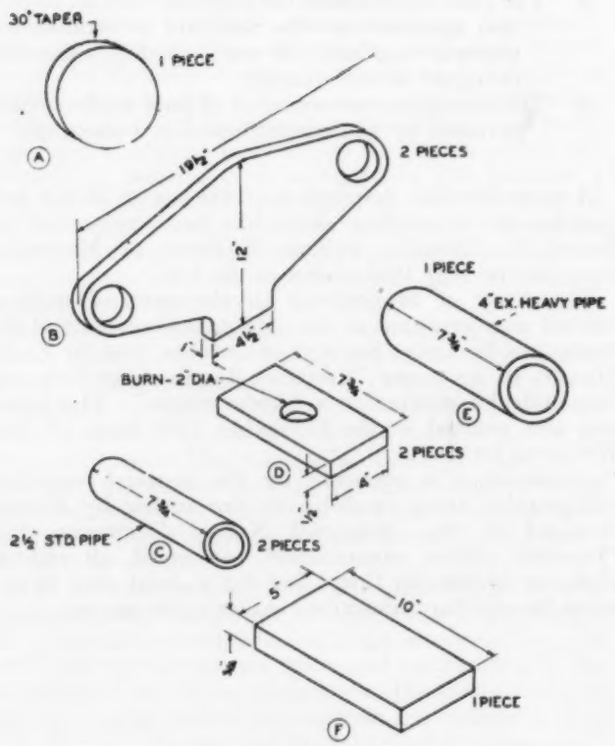


Fig. 3

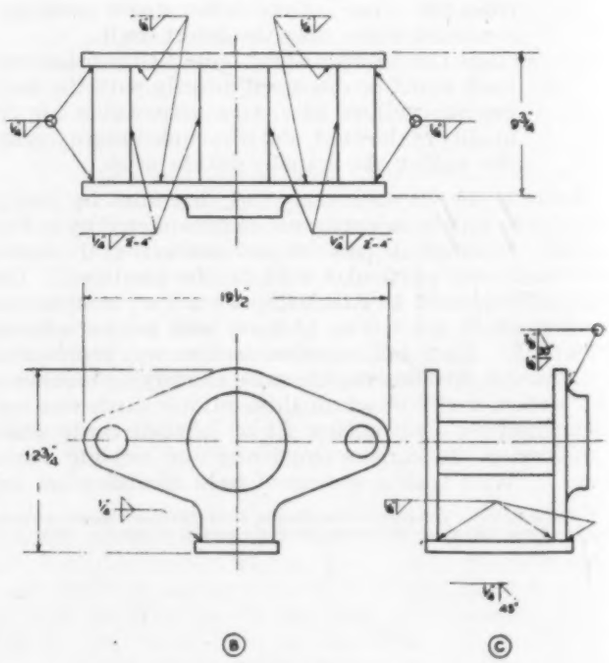


Fig. 4

Pump and Machine Co. This company is also planning new products for arc-welding fabrication.

A complete change in design is not necessary here since the welded piece must serve the same purpose and meet the same dimensional requirements as the old part. In spite of this, considerable weight is saved in the welded design, for material is placed only where needed.

With cast steel, the designer must take into consideration the foundry technique which necessitates sufficient metal to insure proper flow in the mold and a solidification sequence to minimize shrinkage cavities. Also, extra metal often must be used in the form of webs and bosses to give the sections sufficient strength to resist the stresses set up during cooling of the solid metal in the mold, especially in the temperature range near the solidification point.

The former cast steel crosshead is shown in Fig. 1. Note the intricate distribution of metal and heavy sections at the central part. The weldment, Fig. 2, is a more efficient design, for there is a weight saving of nearly one-half with a corresponding saving in cost.

The simplicity of the welded design is shown in Fig. 3. These component parts are cut from standard mild steel stock.

(*a*) Circular head cap is flame cut from 1-in. plate and torch bevelled 30° for fillet weld.
(*b*) Head plates are flame cut from 1-in. plate.
(*c*) Spacers are sawed from $2^1/_2$-in. diameter standard pipe.
(*d*) Stiffeners are flame cut from $^1/_2$-in. plate. Hole is flame cut.
(*e*) Main cross member is sawed from 4-in. diameter extra heavy pipe.

The parts are held in a fixture, accurately positioned and fitted up, and tack welded. Complete welding is then done as indicated by the symbols in Fig. 4.

Results.—Actual shop cost of the casting (exclusive of pattern cost) was $84.91. Cost of the weldment is $47.41. Saving: $37.50 or 44.2%. Saving in weight is nearly 50%.

Conclusion.—The key to maximum savings in machine design is to use materials only where needed to meet functional requirements and to apply those materials in such a way as to obtain maximum speed of production.

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THE AMERICAN WELDING SOCIETY

ACTIVITIES – RELATED EVENTS

ADMIRAL VICKERY DIES AT 53*

Vice-Admiral Howard L. Vickery, vice-chairman of the United States Maritime Commission in the second World War, died on March 22nd only a few hours after going to Palm Springs, Calif., in an effort to recover his health. His age was 53.

Built Merchant Fleet

The career of Admiral Vickery was studded with many achievements. A powerful force behind the construction of the nation's vast wartime merchant fleet, he was affectionately called the "miracle man" of the second World War.

He repeatedly emphasized that the nation's shipbuilding program must continue in the pastwar period.

He strongly recommended the construction of the Victory ship rather than the Liberty vessel, maintaining that the former would be more seaworthy in the postwar era. He pointed out that the Victory ship was 13½ ft. longer than the Liberty ship, had 5 ft. more beam and was four to six knots faster. While the Victory ship could not be built as speedily, Admiral Vickery said that it could make more trips than the Liberty.

In August 1943 Admiral Vickery was appointed chairman of a newly formed postwar planning committee to develop long-range plans for the nation's shipping industry. The next month he went to London for a series of conferences with British shipping authorities.

Entered Annapolis in 1911

The future Vice-admiral was born on April 20, 1892, the son of Willis and Anna Louise Vickery at Bellevue, Ohio, and attended the East High School in Cleveland. He entered the United States Naval Academy in 1911 and was graduated in 1915 from Annapolis with a B.S. degree and was commissioned an ensign.

When this country entered the first World War, he was assigned to a ship guarding the first convoy to France.

In 1921 he received a M.S. degree from the Massachusetts Institute of Technology. The previous year he had been assistant to the supervisor of submarine construction in the Navy superintendent constructor's office at San Francisco. From 1921 to 1925 he served as docking and outside superintendent at the Boston Navy Yard.

* Taken largely from New York *Times*, March 22nd.

Vice-Admiral Howard L. Vickery

At the close of 1925 the Haitian Government requested Admiral Vickery's services as a treaty engineer. He remained in that country for three years, returning to become a member of the Navy Bureau of Construction and Repair at Washington, D. C. In 1929 he was appointed technical adviser on shipping to the Governor General of the Philippines.

Saw "Birth of German Navy"

In this capacity he was sent to Germany where Philippine ships were under construction and "watched the official birth of the German Navy." He returned to the Bureau of Construction in 1934 as head of the secret War Plans Section of the design branch and during that year also took graduate courses at the Army Industrial College.

He and Vice-Admiral Emory S. Land, head of the War Shipping Administration, were called "one of the most remarkable combinations in Washington." From 1937 to 1940 Admiral Vickery acted as assistant to Admiral Land. In 1940 Admiral Vickery was appointed a member of the Maritime Commission by President Roosevelt, and the same year a British commission requested American shipyards to build British freighters.

There was a shortage of shipbuilders and, against the advice of others, Admiral Vickery engaged Henry J. Kaiser to expedite the shipbuilding program for the British.

In 1942 he was requested by President Roosevelt to produce 8,000,000 tons of shipping. By April of that year Admiral Vickery announced that more new American ships had been constructed than the number sunk since Pearl Harbor.

The Maritime Commission's goal for 1943 was 18,000,000 tons. Admiral Vickery warned in April of that year that the goal was threatened by man-power shortages. In June he disclosed that ships were down to 56 days average building time, U-boat losses down to one out of 200 ships. What was most important was the disclosure that the United States, since Pearl Harbor, had built shipping equal to the entire tonnage of Great Britain, Japan, Germany and Norway as of January 1941.

He retired Dec. 31, 1945, because of ill health.

Besides his widow, he leaves a daughter, Barbara Willis, and a son, Hugh Blanchard, a lieutenant in the Navy.

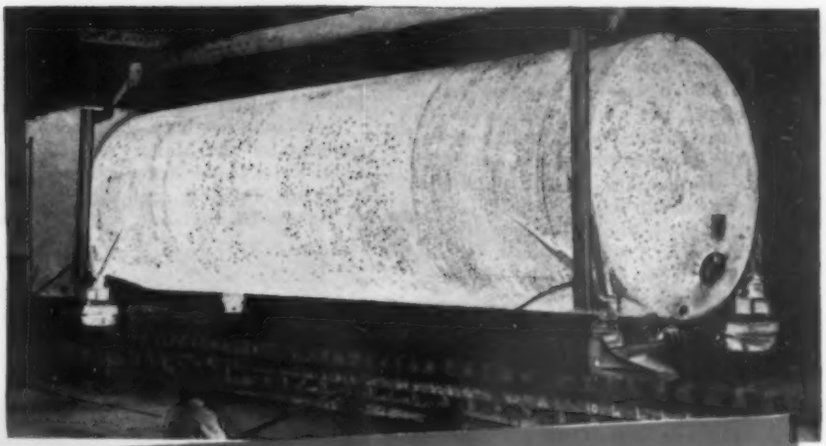
Admiral Vickery has presented several papers before the AMERICAN WELDING SOCIETY and has in various talks given due recognition to the part played by the SOCIETY in the advancement of the knowledge of welding so that it could be applied in wartime production of ships. This year he received the Morehead Medal from the International Acetylene Association. Admiral Vickery was a member of the Welding Research Council at the time of his death.

1946 EDITION UNIFORM BUILDING CODE

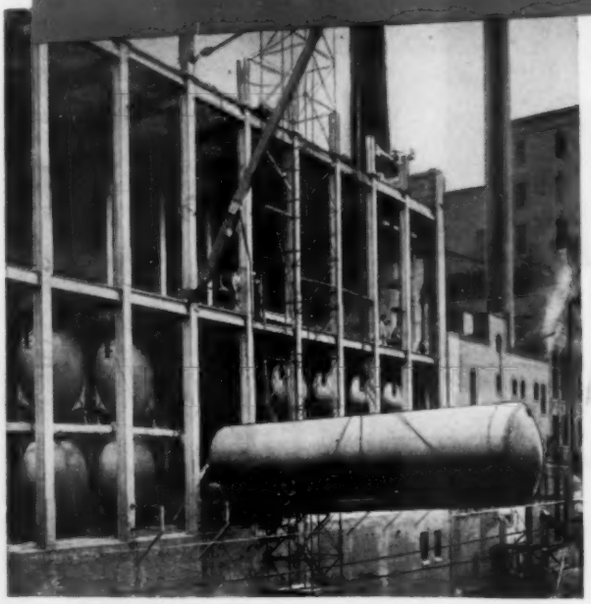
The 1946 Edition of the Uniform Building Code, scheduled for publication Jan. 1, 1946, is now off the press. It contains many important and far-reaching changes since publication of the 1943 Edition. There are revised provisions concerning administration, heavy timber construction, masonry, stairs and exits, chimneys, vents, fireplaces, motion picture projection rooms and heating appliances. For the first time, a chapter on prefabricated construction has been incorporated on the Code, as well as new sections regulating glued construction.

In making these extensive revisions, the Conference answers the insistent public demand for a building code that is modern enough to recognize new materials and elastic enough to permit new uses of old materials. The accepted policy of the Conference of specifying the results desired has been followed throughout, with the single exception of the limiting dimensions

1933 Thousands of man-hours of welding research went into development of a SMITHway Electrode over the weld of which glass coatings could successfully be applied. The result was production of this first large single-piece glass-lined tank, shown emerging white hot from the gigantic furnace.



Out of Welding Research... BETTER BEER



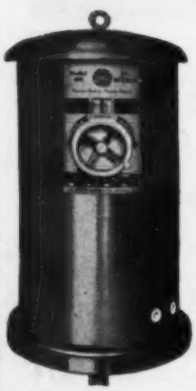
1946 Since the first SMITHway Glass-Lined Storage Tank was built in 1933, hundreds of brewers throughout the world have equipped their lagering cellars with SMITHway glass-lined tanks . . . a combined storage capacity of 39,486,188 gallons.

The Proof Is in Production

The first trail-blazing SMITHway Electrode was produced in 1917. Repeatedly since then, A. O. Smith's continuous welding research has been marked by milestone developments. During the war, SMITHway techniques, proved in peacetime production, made it possible to meet national needs that could not have been met in any other way.

New developments to fill every new need are always in the making at A. O. Smith—in the welding research laboratories, in the plants where more than 320,000 SMITHway Electrodes have been used in daily production.

For detailed specifications of SMITHway Certified Electrodes and their application to specific welding jobs, write for the SMITHway Welding Catalog.



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of masonry-bearing walls specified in Chapter 24. Here, definite dimensions are specified for the use of the architect or engineer who desires to use time-tested construction; but Code specifications do not suppress the ingenuity and imagination of the designer who wishes to depart from the conventional, as long as he does not depart from structural stability.

Copies of the Uniform Code may be obtained from the Colling Publishing Co., 124 W. Fourth St., Los Angeles 13, Calif., at the following rates: For nonmembers of the Uniform Building Code Association—cloth bound, $3.00 each; paper, $2.50. Prices for quantity lots, and prices of copies for members of the Uniform Building Code Association may be obtained by writing the Colling Publishing Co.

1946 A.S.H.V.E. GUIDE AVAILABLE

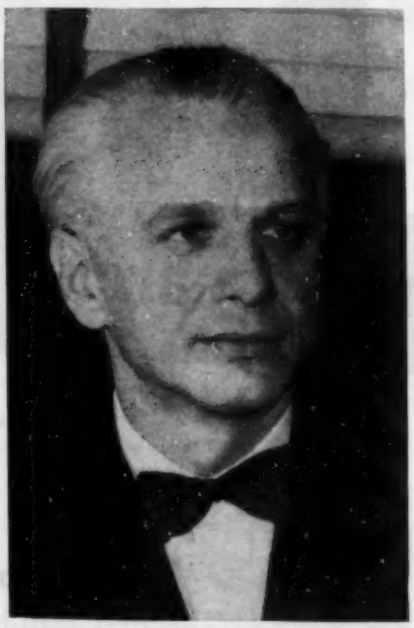
The 24th edition of the "Heating Ventilating Air Conditioning Guide" published by the American Society of Heating and Ventilating Engineers, 51 Madison Ave., New York, N. Y., is just off the press. The technical text contains 51 chapters grouped under the general section headings of Principles, Human Reaction to Atmospheric Environment, Heating and Cooling Loads, Combustion and Consumption of Fuels, Heating Systems and Equipment, Air Conditioning, Special Applications, and Installation and Testing Codes.

DR. HENSEL MADE VICE-PRESIDENT

Dr. F. R. Hensel has been elected vice-president in charge of engineering of P. R. Mallory & Co., Inc., Indianapolis, Ind.

Dr. Hensel has been chief metallurgical engineer for the Mallory company since 1934. He holds degrees from Mining Academy, Freiberg, Saxony; University of Sheffield, England, and Technische Hochschule, Charlottenburg. He is a member of the American Institute of Mining and Metallurgical Engineers, American Society for Testing Materials, American Society for Metals, AMERICAN WELDING SOCIETY, Society of Automotive Engineers, American Association for the Advancement of Science and the British Institute of Metals.

He has presented more than 40 scientific and technical papers before various metallurgical and other scientific societies, and has been granted more than 140 patents on alloys and metallurgical processes. Dr. Hensel is chairman of the Resistance Welding Research Committee of the Welding Research Council.



F. R. Hensel

HOLLUP OFFERS "SELECTRODE CHART"

Tells which electrode to use. This selectrode chart recently issued by the Hollup Corp., a division of the National Cylinder Gas Co., Chicago, guides electrode users in the choice of the correct electrodes for a specific job. Tells which electrode to use, suggests applications, shows currents, positions, physical characteristics, etc.

Included are electrodes recommended for mild, low-alloy and stainless steels, nonferrous and cast iron, surfacing, as well as gas welding rods.

A copy may be had by addressing the Hollup Corp., 4700 W. 19th St., Chicago, Ill.

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PAGE *Welding* ELECTRODES

The PAGE formula for Production Welding Economy

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WHERE:
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S= SAVINGS IN WELDING COSTS

The high quality and uniformity of Page electrodes and rods are taken for granted by experienced welders. Production welding economy is a matter of (1) selection of the right rod and (2) welding "know-how." Both are offered by PAGE. For electrodes or gas rods and for information about their most economical use, get in touch with your PAGE distributor.

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A.S.T.M. COMMITTEE A-1 ON STEEL

The heavily attended series of meetings of A.S.T.M. Committee A-1 on Steel held in Pittsburgh during A.S.T.M. Committee Week were featured by rather intensive activity in the fields of structural steel, bar steels, both carbon and alloy, and pipe and tubing. Numerous recommendations in other fields covered spring wire, forgings, steel castings and steel for boilers and pressure vessels.

The Advisory Committee acted to establish a class of Honorary Membership which will recognize the outstanding activities of a number of long-time A-1 members, and approved the complete reorganization of Subcommittee XIII on Methods of Testing. Small sections will be appointed to channel the activities of tension testing, speed of testing, bend testing, interpretation of numerical requirements, etc.

Low Temperature Applications

To meet the expressed need for guidance in establishing not only specific requirements but tests for materials used at extremely low temperatures, two subcommittees covering boiler and pressure vessel steel and pipe and tubing have appointed special sections to develop information and data.

Structural Steel

There was intensive discussion of a specification to cover structural steel for welding, and instead of attempting to set up carbon and manganese limination in the widely used Specification A 7, an attempt will be made to draft a separate specification which eventually might replace A 7. The present physical properties are to be retained in the specifications for low-alloy structural steel (A 242). These are such as to justify a design stress of 27,000 psi. Because of confusion which would result if requirements on rivets of similar composition and strength were incorporated in this specification, a separate document will be drafted.

Two new specifications for carbon steel plates were approved for submission to letter ballot, one to cover material over 2 in. in thickness with a special silicon content, intended for use for machine parts and general construction by gas cutting, welding or other means. The companion specification covers material 2 in. and under. These eventually will replace existing specification A 10 for Mild Steel Plates 55,000 to 65,000 psi. tensile strength, and A 78, Low Strength Plates for Welding. As a result of recommendations from the American Iron and Steel Institute, revised tables covering permissible variations will be embodied in the plate and structural specifications.

Steel for Pressure Vessels

A new specification combining existing standards A 70 and A 89, carbon steel plates of flange and firebox quality for boilers was accepted. It covers material up to 2 in. in thickness and provides three grades, 60,000, 65,000 and 70,000 psi. minimum tensile, with corresponding yield points of 24, 27 and 30%.

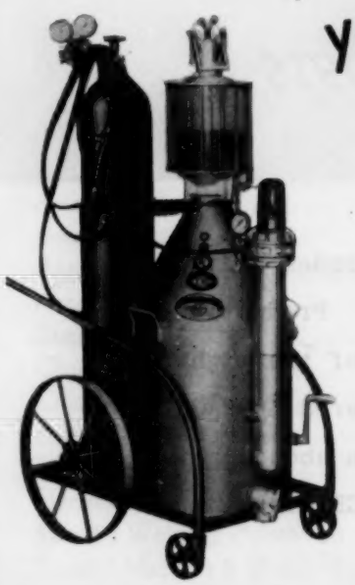
REPAIR OF CASTINGS

Repair welding of gray iron castings was among the wide-interest subjects programmed for discussion at the 50th anniversary convention of the American Foundrymen's Association in Cleveland's Public Auditorium May 6th to 10th, according to T. E. Eagan, chief metallurgist, Cooper-Bessemer Corp., Grove City, Pa., who is chairman of the association's gray iron division.

The welding session programmed by the society's gray iron division was scheduled for the afternoon of May 10th, Chairman was Edgar C. Jeter of the Ford Motor Co., Dearborn, Mich., with John Crowe of Air Reduction Sales Co., New York City, assisting as co-chairman.

The "Metallurgical Aspects of Repair Welding of Gray Iron" was thoroughly and interestingly covered in a paper prepared by three welding experts of General Motors Corp.: J. A. Blastic of the Detroit Deisel division, J. A. Griffin of the Pontiac Motor division, and J. M. Diebold of the General Motors Truck and Coach division. A companion paper of equal interest, entitled "Physical Aspects of the Welding of Gray Iron," was presented by W. Pfander of the Ford Motor Co., Dearborn.

A third discussion which held the attention of gray iron foundrymen dealt with the "Welding of Heavy Gray Iron Sections." Speaker was L. J. Larson, welding engineer of the engineering development department of Allis-Chalmers Manufacturing Co., Milwaukee.



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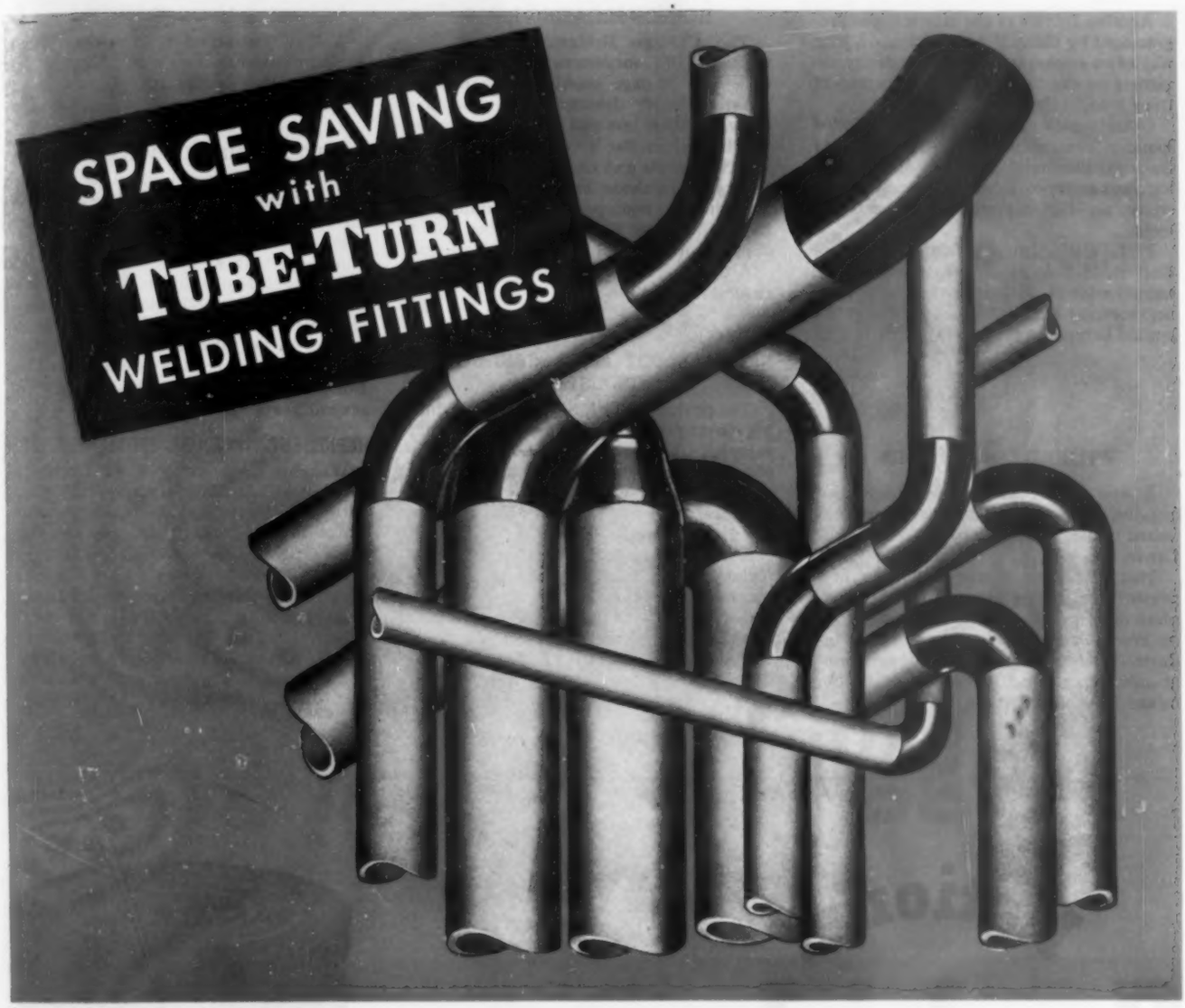

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Consult your favorite piping authority and see your Tube Turns distributor. For more information on superior Tube-Turn welding fittings and pace-setting installations in many industries, write for Catalog 111.

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TUBE-TURN TRADE MARK **tt** ***Welding Fittings and Flanges***

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Another feature of the nine sessions programmed by the A.F.A. gray iron division was a two-session symposium for design engineers on the "Engineering Properties of Gray Iron," scheduled for May 8th.

Other topics of the congress included foundry control methods, inspection of castings, industrial job training, humanics, sand research, job evaluation and time study, accident prevention and cost systems.

F. J. Walls, International Nickel Co., Detroit, A.F.A. president, delivered his annual address as president at the business meeting May 9th and presided at the annual banquet Friday, May 10th.

WELDING LENS BULLETIN

A new leaflet on welding lenses for goggles, helmets and handshields has been issued by Eastern Equipment Co., Willow Grove, Pa.

This attractive literature is the first presentation of its type and gives complete descriptions as well as photographs on every type of welders' lens and on industrial safety lenses for chipping and grinding operations. Copies may be obtained by addressing the company.

HORTON FLOATING ROOF

The Chicago Bridge and Iron Co., Chicago, Ill., announces the publication of a new 12-page booklet "The Horton Floating Roof" discussing the reduction of evaporation loss and the elimination of fire hazard in flat-bottom tanks storing volatile liquids and chemicals.

Gaging methods employed with flat-bottom tanks equipped with the improved Horton Floating Roof are described and a diagram of a typical installation is shown.

A copy of this booklet will be sent on request.

NICKEL ALLOY STEEL CASTINGS IN INDUSTRY

The progress which has been made during recent years in steel foundry technique, especially as regards the improvements obtained through the use of alloying elements, has stimulated interest in the use of nickel alloy steel castings for machinery and equipment parts.

A new booklet just issued presents pictorially, with a minimum of text, a representative selection of applications for which castings of tough, strong nickel-alloy steel are currently being used.

Copies available from The International Nickel Co., Inc., 67 Wall St., New York 5, N. Y.

WILLIAMSON PROMOTED

A. J. Williamson, for seven years Chief Metallurgist, has been made Plant Manager at the Summerill Tubing Co., Bridgeport, Pa.

HARRISON JOINS UNIVERSAL POWER

Ralph C. Harrison has joined the Universal Power Corp. as Welding Engineer for sales of arc and oxyactylene equipment, high frequency induction heating and power plants.

He is well known in the Lake Erie Region having been active in sales of similar equipment.

Prior to his sales work he was welding instructor for the Cleveland Board of Education on their NDP program for several years.

REPRESENTATIVE PRECISION WELDERS

Welding Engineering Sales Corp. located at 110 E. 42nd St., New York City, with branch offices at 150 Causeway St., Boston, Mass., and 1 W. Genesee St., Buffalo, N.Y., have been appointed exclusive representatives for Precision Welder and Machine Co. of Cincinnati, Ohio, handling a complete line of resistance welding machines. Their personnel, trained in welding engineering and service will cover New York State, New England and Northern New Jersey.

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Full Protection On the Job . . . Near the Job

AO Duraweld Goggles have new style louvers to prevent ventilation areas from clogging—so designed that stray light rays and sparks cannot reach the eyes. They fit comfortably, permit wide range of vision, help welders lay better beads faster.

AO Safety Goggles with 6-Curve Calobar Super Armorplate lenses are ideal for wear in the vicinity of welding operations and wherever general glare conditions exist. Call or write your nearest AO Safety Representative for complete details.

American Optical COMPANY *Safety Division*

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NEW HANDBOOK ON COPPER ALLOY WELDING

Welding and Brazing of Copper and Copper Alloys is the title of a 32-page handbook of procedures and materials just published by C. E. Phillips & Company, 2750 Poplar St., Detroit 8, Mich. There are three principal divisions in this comprehensive treatise. In the introductory section important definitions of materials and processes are given, accompanied by a table of compositions and properties of the most commonly welded and brazed commercial copper alloys. This is followed by general information as to the welding characteristics of these materials, suggestions for preparing parts for welding, design of joints and the use of jigs and fixtures. A chart is included which indicates that each of the common copper alloy groups can be welded or brazed by several different methods and tells the preferred materials to be used with each method.

In the second section of the book each of the common copper alloys is discussed individually. Information is given as to composition, physical properties, forms usually supplied, suitability for hot and cold working and special welding characteristics. Then the applicability of each of the welding and brazing processes to the alloy is explained, recommendation is made as to the preferred method to use for joining the alloy, the correct welding or brazing material is indicated, and tables of welding procedure are given for the processes that are recommended. The metallurgical nature of typical welded and brazed joints is illustrated by micrographs and photomicrographs. The text does not attempt to establish any one process as preferable for all copper alloys but rather makes it a point to study each alloy separately and select the process which promises best results.

A third and final section is devoted to welding and brazing materials for copper and copper alloys, and the general plan of treating each material separately is followed. Information supplied includes composition, characteristics, properties of deposit, purposes for which used, application procedures, recommended uses, standard sizes, lengths and packaging. Copies may be obtained by writing to C. E. Phillips & Co., 2750 Poplar St., Detroit 8, Mich.

H. R. E. AUSTIN

H. R. E. Austin, formerly located in Kansas City as district manager for the National Cylinder Gas Co., is now Sales Manager for Rex Welder and Engineering Co., Kansas City, Mo.

NORTON STARTS WELDING SUPPLY BUSINESS

Mr. Roy Norton, member of the Society, has opened a welding supply business in Milwaukee to be known as the Norton Welding Equipment Co.

Mr. Norton originally represented the Harnischfeger Corp. in the Milwaukee and Wisconsin area as a Welding Sales Engineer. Later, he joined Ampco Metal, Inc., Milwaukee, Wis., as Manager of their Welding Div., and from* there, moved to the Alloy Rods Co., York, Pa., as General Sales Manager. Mr. Norton resigned this position effective Feb. 22, 1946.

The major lines being handled by the new company are Champion Rivet, Glenn-Roberts, Alloy Rods and Victor Equipment. In addition to these major lines, a complete line of oxyacetylene and electric welding accessories are also being distributed.

FIFTY YEARS OF PUBLIC SERVICE

Fifty years ago a small group of public-spirited New Englanders met after work in a small Boston, Mass., office and declared war on fire. From that humble David-and-Goliath beginning, the National Fire Protection Assn. was born and grew into the present world-wide, independent, technical and educational organization that it is today with members in 37 countries. Global honor will be paid to the N.F.P.A. at its 50th anniversary meeting in Boston, June 3–7, 1946.

The National Fire Protection Association is the international clearing house for all information that is authoritative on the subject of fire protection and fire prevention. It has been a faithful servant of the industrial world.

HARD FACING BULLETIN

A new technical bulletin covering hard surfacing and the use of Hardex Electrodes in building up surfaces for resistance to shock and abrasion is offered by Metal & Thermit Corp., 120 Broadway, New York 5, N. Y. The bulletin contains 16 pages of helpful information concerning such factors as effect of temperature and cooling rates on deposited metal, selection of the proper grade of rod, and recommended welding techniques. Copies will be mailed on request.

ALL-WELDED U.S.S. COR-TEN HOPPER CAR

In the 11 years since the introduction of U.S.S. Cor-Ten, car builders and railroads have used this versatile high-strength steel in more than 65,000 freight cars with an average saving in dead weight of more than $2^1/_2$ tons per car. Continuing its pioneering, the Railroad Research Bureau of United States Steel Corp. Subsidiaries has studied the operating records of these cars and now presents an all-welded, lightweight U.S.S. Cor-Ten hopper car of new design for inspection by railroad officials and car builders. This new car, built to order for Carnegie-Illinois Steel Corp., will be first shown at Roanoke, Va., on April 2nd and 3rd, with subsequent appearances at other railroad centers.

The high strength of U.S.S. Cor-Ten and its superior atmospheric corrosion resistance have permitted reductions in the thickness of sections, and assure longer service life for the car. Of particular interest are the new types of joints embodied in the construction. These are all welded and simplify construction, provide tight seals against moisture and eliminate laps.

When empty the new all-welded car weighs only 33,500 lb., a saving of 6540 lb. over the A.A.R. standard hopper car built of carbon steel. This saving has been translated into increased cubic capacity, which allows more revenue freight each time the car is loaded. Because of its reduced weight, the car is equipped with empty-load brakes.

In general, the car does not differ radically from the lines of the conven-

NEW Low Temperature ELECTRODES

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A Coated Electrode for the Metallic Arc Welding of Bronze, Brass, Copper

For reduced production costs—can be used with AC and DC—deposits sound welds with good corrosion resistance—a close color match to red bronzes and yellow brasses—tensile strength 45,000 psi.

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24—for cast iron—no preheat—AC-DC
24B—for cast iron—AC-DC
30—for copper—AC-DC
2100—for aluminum alloys—DC

and these EutecChroms:

2—for hard overlays on worn parts—AC-DC
4—for work-hardening overlays—AC-DC
6—for overlays on tool steel—AC-DC
8—for high hardness, impact strength—AC-DC
12—for extremely hard overlays—AC-DC

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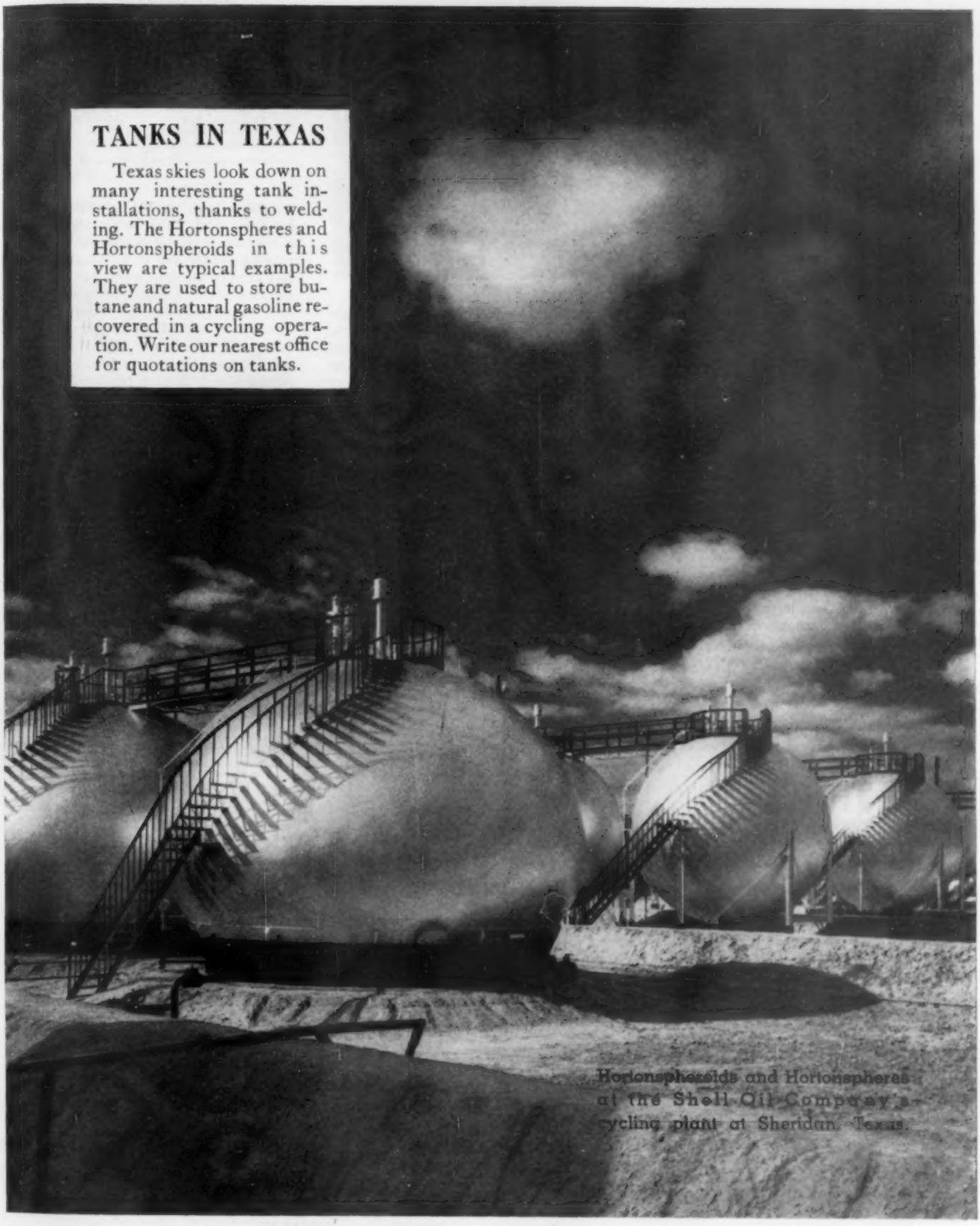
FREE Complete new booklet on fabricating with EUTECTIC Low Temperature Welding Rods.*


TANKS IN TEXAS
Texas skies look down on many interesting tank installations, thanks to welding. The Hortonspheres and Hortonspheroids in this view are typical examples. They are used to store butane and natural gasoline recovered in a cycling operation. Write our nearest office for quotations on tanks.
Hortonspheroids and Hortonspheres at the Shell Oil Company's cycling plant at Sheridan, Texas.

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Proposed Itinerary for U.S.S. Cor-Ten All-Welded Hopper Car

City	Date
Roanoke, Va.	April 2–3
Washington, D. C.	April 8–9
Philadelphia, Pa.	April 15–16
New York, N. Y.	April 22–23
Pittsburgh, Pa.	April 30–May 1
Cleveland, Ohio	May 7–8
Cincinnati, Ohio	May 14–15
St. Louis, Mo.	May 21, 22, 23
St. Paul, Minn.	June 5–6
Chicago, Ill.	June 19–20–21

Comparative Data

	New All-Welded U.S.S. Cor-Ten Car	A.A.R. Std. Design Carbon Steel
Light weight*	33,500 lb.	40,040 lb.
Inside length	34 ft. 2 in.	33 ft. 0 in.
Inside width	9 ft. $9^{13}/_{16}$ in.	10 ft. 4 in.
Height	11 ft. 0 in.	10 ft. 8 in.
Cubic capacity		
Level	2273 cu. ft.	2145 cu. ft.
10-in. heap	2553 cu. ft.	2408 cu. ft.

* With one-wear wrought steel wheels.

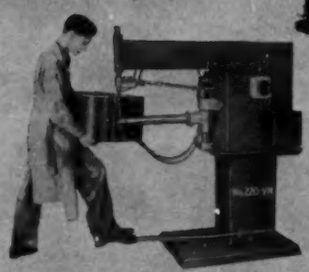
tional A.A.R. standard design. For economy and simplification in fabrication, the use of standard sections and plates with straight trim and simple cold bends was one of the basic concepts of the design. Hot pressing and elaborate die work were avoided. The car structure is designed for subassemblies which will facilitate assembly and permit position welding, these subassemblies of under-frame sides and ends being all welded together to form the complete car.

Protruding structural members and seam ledges have been eliminated from the interior of the car by means of outside stake side construction. This side framing has additional horizontal stiffness which compensates for the omission of the inside diagonal center braces. Such a smooth interior surface permits the free flow of lading when unloading and helps avoid damage to the car by mechanical devices used in unloading or loading. Ledges and pockets where moisture can collect are also eliminated, thus reducing the possibility of corrosive attack.

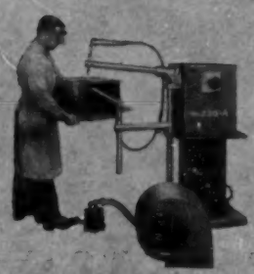
To obtain maximum unloading area in the hopper door openings, and to reduce weight, a new, welded tubular center sill has been used. This facilitates the use of a one-door opening across the car. The tubular center sill is terminated at the face ends of the draft gear back stops with the face plates welded to the ends of the still, thus transmitting the buffing forces directly to the full cross section of the center sill. Standard Z-26 draft sills extending from the bolster to the end of the car form a draft gear pocket of standard dimensions. The draft sills are secured to the tubular center sill by welds which will develop strength equal to the full cross section of the sills, all welds running parallel to the line of stress.

The hopper sheet, which is formed by two simple cold bends, extends in one piece from one side of the car to the other. Its sloping sides engage and are welded to the corresponding slopes of the angles forming the bottom chords of the side girders. Specially designed longitudinal braces extending from the bolster to the end sheet assure stiffness. The body bolster is made up of a Carnegie wide flange beam with a pressed plate extension

SPOT • BUTT • ARC
WELDERS



AIR, FOOT or MOTOR Operated Press Type Welders of All Sizes.



We manufacture a complete line of resistance spot welders from ¼ to 300 KVA for all types of welding. There is an EISLER WELDER for every purpose.

Transformers of all types.

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Preventing Welded Parts From Rusting

Rust gets in its destructive work on held ferrous parts both before and after welding. You can prevent this costly peril to production simply by immersing work in Oakite Special Protective Oil.

Rust prevention by this new, time-saving Oakite method eliminates expensive pre-drying equipment . . . permits further processing to move swiftly, smoothly.

20-page booklet gives interesting details . . . tells how to neutralize finger print corrosion; rust-proof stored tools and parts. Send for FREE copy TODAY!

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MATERIALS · METHODS · SERVICE · FOR EVERY CLEANING REQUIREMENT

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on the top flange to facilitate the connection to the sloping floor sheet and to provide a more yielding contact between the floor and the bolster.

Each side is a main subassembly. The side sheeting is made up of two longitudinal sheets, the heavier being in the lower portion, which encounters the greater wear and abuse. This heavier sheet extends from bolster to bolster and serves as a framing member for the attachment of all cross members and floor sheets. The upper sheet is of lighter gage and also extends from end to end of the car. These sheets are welded to a frame structure consisting of channel section vertical posts and top chord and an angle section side sill or bottom chord. The latter is inclined, forming a water-shedding shelf and providing the proper slope for the attachment of the hopper sheets.

Employment Service Bulletin

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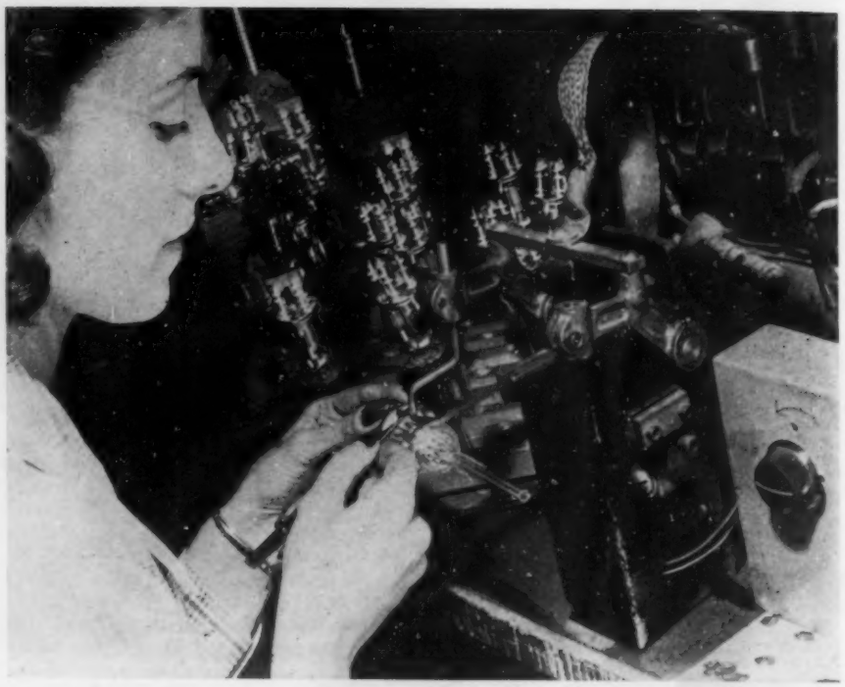
V-90. Help Wanted. Supervising Welding Engineer required by large southern shipyard. Should be thoroughly familiar with structural, ship and pipe welding design and practice. Write, fully detailing qualifications, salary requirements, etc. to above box number.



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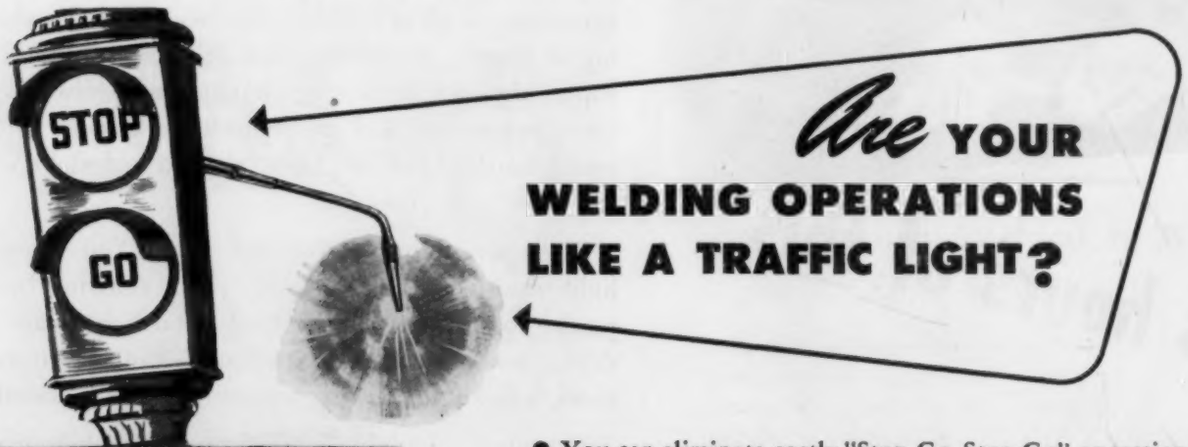
During the war, the Armed Forces used huge quantities of these tubes to fight the enemy—industries need them in war and peace. In the completed tube, the "gun" assembly "shoots" electrons at the phosphorescent screen, causing it to fluoresce. This action paints the basic picture for the eye to perceive—vital to Radar in World War II—source of enjoyment in postwar television.



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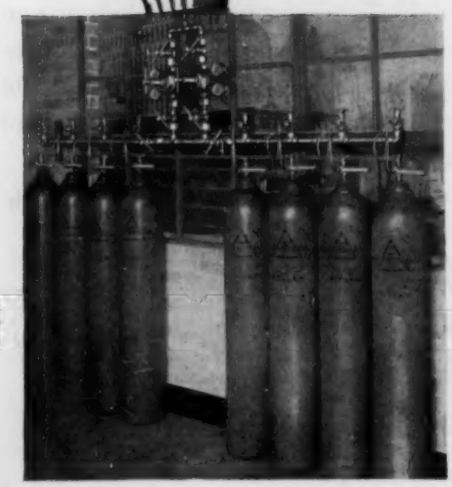

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GET THIS BULLETIN
describing all of the basic types of Federal Resistance Welders.

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List of New Members

March 1 to March 31, 1946

ATLANTA

Hanner, Melvin (B), Westinghouse Elec. Corp., 1299 North Side Dr., N. W., Atlanta, Ga.

BOSTON

Leahey, William E. (C), 11 Blossom St., Worcester, Mass.

BRIDGEPORT

Wollkind, Monroe (C), 56 Winfield St., E. Norwalk, Conn.

CHATTANOOGA

Born, Jesse James (C), Route 1, Rossville, Ga.
Soyars, John M. (C), c/o National Cylinder Gas Co., 238 So. Front St., Memphis, Tenn.

CHICAGO

Castro, Carlos (C), c/o Operadio Mfg. Co., St. Charles, Ill.
Kellam, Fred (C), Public Roads Adm., 2938 E. 92nd St., Chicago 17, Ill.
Perry, John L., Jr. (C), Air Reduction Sales Co., 332 So. Michigan Ave., Rm. 604, Chicago 4, Ill.
Romanyak, James (C), 5128 So. Wolcott Ave., Chicago 9, Ill.
Swanson, Lawrence F. (C), 604 E. 8th St., Gibson City, Ill.

CINCINNATI

Gottschalk, Lionel J., Jr. (C), National Elec. Weld. Mach. Co., 831 Temple Bar Bldg., Cincinnati, Ohio.

CLEVELAND

Brown, Alexander C., Jr. (C), Air Reduction Sales Co., 1108 Williamson Bldg., Cleveland 14, Ohio.
Byers, Charles H., Jr. (C), Fabriweld Corp., 802 E. 67th St., Cleveland, Ohio.
Cullin, Ted P. (B), Bernard & Co., 225 Hanna Bldg., Cleveland, Ohio.
Curtis, Arthur A. (C), Fabriweld Corp., 802 E. 67th St., Cleveland, Ohio.
Hathaway, John E. (B), Euclid Road Machy. Co., N. Chardon Rd., Euclid 17, Ohio.
Kirkland, R. G. (C), Kirk Welding Co., 10410 Madison Ave., Cleveland, Ohio.
Lopatich, Frank J. (B), 20187 Goller Ave., Euclid 19, Ohio.

DETROIT

Brumby, Walter William (B), English Elec. Co. of Canada, Ltd., St. Catherines, Ont., Canada.
Carson, Edward (C), 154 N. Berkshire Rd., Pontiac 3, Mich.
Hoffmeyer, Paul (C), Hoffmeyer Machine Shop, R. 1, Wheeler, Mich.
Loftus, A. J. (C), C. E. Phillips & Co., 2750 Poplar St., Detroit 8, Mich.
Sylvester, Joseph P. (B), Westinghouse Elec. Corp., 5757 Trumbull Ave., Detroit, Mich.

INDIANA

Sparks, Thurman I. (B), Noblitt-Sparks Ind., Inc., Greenwood, Ind.

KANSAS CITY

Timmons, James H. (B), 4316 Indiana Ave., Kansas City 4, Mo.

LOS ANGELES

Aufdemberg, Oliver H. (C), 10146 San Gabriel St., South Gate, Calif.
Brown, Clifford A. (C), Fluor Corp., Ltd., P. O. Box 6861, E.L.A. Branch, Los Angeles 22, Calif.
Carter, John D. (C), 1851 W. 32nd St., Long Beach 6, Calif.
Higgins, A. J. (C), Rheem Mfg. Co., 4361 Firestone Blvd., South Gate, Calif.
Hupp, George A. (C), 300 San Jose Ave., Compton, Calif.
Manson, A. R. (C), 411 Valley St., El Segundo, Calif.
McGinley, Francis V. (C), 1561 Chickasaw Ave., Los Angeles, Calif.
Sloan, George W. (C), 1722 W. 108th St., Los Angeles, Calif.
Sorenson, Chris H. (C), 343 Washington Ave., Hawthorne, Calif.
Welz, Stephen J. (B), 1111 So. Catalina Ave., Redondo Beach, Calif.

MAHONING VALLEY

Noftsinger, O. L. (C), 1229 Prospect Ave., N. W., Warren, Ohio.
Porter, Fred N. (C), Park & Lattin Sts., Cortland, Ohio.
Reid, Harry H. (C), 252 E. Main St., Newton Falls, Ohio.
Schauerte, Gerald E. (C), 465 Mahoning Ave., Warren, Ohio.

MARYLAND

Holland, Guy C. (C), 2900 Durran Rd., Apt. A-4, Dundalk, Md.

MILWAUKEE

Foat, Roland R. (C), 2249 Aver Pk., Pewaukee, Wis.
Herried, Millard (C), 1575 So. 44th St., Milwaukee 14, Wis.
Soth, Max R. (B), Westinghouse Elec. Corp., 538 N. Broadway, Milwaukee 2, Wis.

NEW ORLEANS

Hughes, William L. (B), Oliver H. Van Horn Co., Inc., 1742 St. Charles Ave., New Orleans, La.

NEW YORK

De Graw, Seneca L. (C), 55—91st St., Brooklyn 9, N. Y.
Flanagan, Harold H. (C), 3127—83rd St., Jackson Heights, N. Y.
Giagola, Charles (C), 6505 Central Ave., Glendale 27, N. Y.
Jungbluth, Josef (C), 175 Maple Ave., Rockville Centre, N. Y.
Ricken, Charles B. (C), G. M. Ketcham Mfg. Corp., 81 Washington St., Brooklyn 1, N. Y.
Zacharkow, Walter (C), 53-130—63rd St., Maspeth, L. I., N. Y.

NORTHWESTERN, PA.

Wetherall, Thomas A. (C), 715 German St., Erie, Pa.

OKLAHOMA CITY

Cribbs, James S. (C), 3803 E. 21st Pl., Tulsa, Okla.
Murray, Glen D. (C), P. O. Box 4511, Oklahoma City, Okla.
Robson, L. D. (C), 37 So. East 32nd St., Oklahoma City, Okla.
Rogers, O. B. (C), Box 812, Drumright, Okla.

PEORIA

Baldwin, Harold (C), 116 Stever St., Peoria, Ill.
Hoelscher, Raymond C. (C), 607 N. Jefferson Ave., Peoria 3, Ill.

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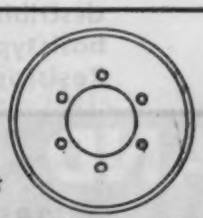
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Mild Steel

	AWS Type
RACO 7	E-6010
RACO 11	E-6011
RACO 8	E-6012
RACO 13	E-6013
RACO 20	E-6020
RACO 5	E-6030
RACO Ferritic	AC-DC

High Tensile Steel

RACO 74	E- 7010
RACO 8010	E- 8010
RACO 9010	E- 9010
RACO 10010	E-10010
RACO 7011	E- 7011
RACO 8011	E- 8011
RACO 9011	E- 9011
RACO 10011	E-10011
RACO 64	E- 7020
RACO 8020	E- 8020
RACO 9020	E- 9020
RACO 10020	E-10020

STAINLESS STEEL ELECTRODES

	AISI Type
RACOLLOY 18-8	308
RACOLLOY 18-8 CB	347
RACOLLOY 18-12 (2-3% Mo)	316
RACOLLOY 18-12 (3-4% Mo)	317
RACOLLOY 25-12	309
RACOLLOY 25-12 CB	309+CB
RACOLLOY 25-20	310
RACOLLOY 19-9	307
RACOLLOY 430	430
RACOLLOY 330	330
RACOLLOY 502	502
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AC-DC, DC Titania, and DC lime coatings are supplied in all grades except 430, 330 and 502

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RACO 45 AC-DC - 40-50 C Rockwell
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Electrode for Cast Iron Welding

RACOLLOY Ni—Nickel Deposit

Electrode for Welding ARMCO Aluminized Steel

RACO Fer-Al AC-DC

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Supplied in catchweight coils, rewound coils on steel bands for automatic welding or cut to 18" lengths.

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Supplied in rewound coils on steel bands for automatic welding.

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Supplied in catchweight coils or cut to 14" or 18" lengths.

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RACO High-Tensile (1% Mn)
Supplied in coils or cut to 36" lengths

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Kluth, Arthur F. (C), A. O. Smith Corp., 1044 Commercial Trust Bldg., Philadelphia 2, Pa.

PITTSBURGH

Van Maldeghem, George (B), Box 49, Beaver, Pa.

PORTLAND, ORE.

Gallaher, M. C. (C), Gallaher Welding Co., 401 So. Second St., Corvallis, Ore.

PUGET SOUND

Johnson, Frank (C), Flohr & Co., Metal Fab., 916 12th Ave., Seattle 22, Wash.

ROCHESTER

Giordano, Joseph V. (C), 92 Myrtle St., Rochester 6, N. Y.
Kreder, Fred L. (C), 269 N. Clinton Ave., Rochester 5, N. Y.

ST. LOUIS

Kearney, Paul (C), Acme Butane Co., Carmi, Ill.

SAN FRANCISCO

Berner, Leo (B), 1682 Naglee Ave., San Jose 11, Calif.
Joyal, Frank F. (C), 1427 Larkin St., Apt. 8, San Francisco, Calif.
Seward, Cliff (B), Shober Sales, Inc., 733 So. Van Buren, Stockton, Calif.

SOUTH TEXAS

Bramblett, T. L. (B), Bramblett & Allen Welding Supply Co., P. O. Box 306, Tyler, Tex.
Cross, William Morgan (B), 1006 English, Houston 9, Tex.
Estes, Ralph R. (C), 7704 Kingsley, Houston 12, Tex.
Lonsford, Claude M. (B), Irvinton Cts., Apt. 443, Houston 9, Tex.

WASHINGTON, D. C.

Koenig, Dr. Benjamin A. (C), 115 E. 116th St., New York 29, N. Y.
Nagley, Forrest R. (C), 4439 17th St., N., Arlington, Va.
Phillips, Edward Ford, U.S.C.G. (C), Merchant Marine Technical Div., 1300 E. St., Rm. 5316, Coast Guard Bldg., Washington, D. C.
Sarelas, Nicholas P. (C), Metallurgical & Testing Section, Naval Gun Factory, Washington, D. C.
Schilling, Frederick V. (C), 7006 Allison St., Landover Hills, Hyattsville, Md.

WESTERN MASS.

Lyman, Louis A. (B), Ornamental Iron Shop, 40–50 Main St., Springfield, Mass.

WESTERN NEW YORK

Breymeier, R. Thomas (C), Union Carbide & Carbon Res. Lab., 4625 Royal Ave., Niagara Falls, N. Y.
Russ, James J. (C), Whitehead Metal Prods. Co., 254 Court St., Buffalo 2, N. Y.
Swan, David (C), Union Carbide & Carbon Res. Lab., 4625 Royal Ave., Niagara Falls, N. Y.

NOT IN SECTIONS

Andersen, Aksel (C), Tech Univ. of Norway, Trondheim, Norway.
Caillard, Jean (C), Esablissements Caillard & Co., 20 Rue De Prony, Le Havre, France.
Christensen, Frede (C), c/o ESAB, Gothenburg, Sweden.
Foreman, John J., S.F. 3/c 2757834 (B), 143 N.C.B., "ABCD", Co. C, Hut C 11, c/o F. P. O., San Francisco, Calif.
Heck, Walt Conaway, Lt. Jg (C), U.S.S. Seneca, "ATF-91," c/o F. P. O., New York, N. Y.
Kjellberg, Bjorn Oscar (B), c/o ESAB, Gothenburg, Sweden.
Kops, Frederick Carl (C), A.B. ASEA Svetsmaskiner, Stockholm 20, Sweden.
Lefevre, Marcel (B), La Soudure Electrique Autogene, 62 Rue Des Deux-Gares, Brussels, Belgium.
Mever, Ing. Svend Aage (B), Assengd., 1, Kobenhavn, Denmark.
Mjelde, Ing. Mons (B), 14, Hammerichsgade, Kobenhavn, Denmark.
Sarazin, R. (B), La Soudure Electrique A L'Arc, 47–49 Bd De Levallois, Nevilly-S-Seine, France.
Sjoman, Per Ungve (B), c/o ESAB, Gothenburg, Sweden.
Torbjornsen, Einar (B), N. A. Gas-accumulator, Chr. Augustsgt 7B, Oslo, Norway.

Members Reclassified

During Month of March

CHICAGO

Itkonen, John (from C to B), 4012 W. Armitage Ave., Chicago 39, Ill.

NEW YORK

Singleton, Jack (from C to B), American Inst. of Steel Const., 101 Parke Ave., New York 17, N. Y.

SAN FRANCISCO

Peralta, Roy W. (from D to C), 5179 Coronado Ave., Oakland 9, Calif.

SECTION ACTIVITIES

BOSTON

The Annual Meeting of the Boston Section was held on April 1st at the Engineers' Club, preceded by a dinner. The officers elected for the fiscal years are as follows: *Chairman*, H. G. Austin, Lukenweld, Inc., Boston; *Vice-Chairman*, W. B. Strathdee, Westinghouse Electric Corp., Boston; *Secretary-Treasurer*, P. N. Rugg, Boston Edison Co.; *Trustee*, L. F. Jackson, The Linde Air Products Co., Boston. *Directors for two years:* M. S. Burton, M.I.T., Cambridge; L. I. Dexter, Tower Iron Works, Providence; J. Donovan, Artisan Metal Products Inc., Boston.

R. F. Wyer of the General Electric Co., presented an illustrated address on "Cost Reduction with A.-C. Welding." Mr. Wyer's address was illustrated by slides and a motion picture on "The Story of A.-C. Welding."

BRIDGEPORT

At the March 21st meeting of the Bridgeport Section, Lloyd Raymond, Metallurgist, Singer Mfg. Co., Bridgeport, spoke on the subject "Hydrogen Copper Brazing." Slides and a film, "Sports Reel," were also shown.

CANADIAN

The sixth meeting of the 1945–46 season of the Montreal Chapter was held on Monday, March 18th, in the Auditorium of the Montreal Technical School. "Control of Quality and Methods of Inspection in Welding" was presented by H. J. Nichols, Welding Metallurgist, Bureau of Mines, Ottawa.

The Toronto Chapter of the Canadian Welding Society held its seventh meeting of the 1945–46 season on Monday, April 1st, in the Mining Building, University of Toronto. This was a "Stump the Experts Night" with six experts: G. N. Sale of the Dominion Oxygen Co. Ltd.; Otto Klein, Steel Co. of Canada Ltd.; R. F. Pulver, American Brass Co.; W. J. Stayura, Canadian Liquid Air Co. Ltd.; J. McMulkin, Ontario Research Foundation; W. Amos, Ferranti Electric Ltd., and as Chairman: R. Eric Crawford, Editor, *Canadian Machinery & Mfg. News*, Toronto.

The Hamilton Chapter held its seventh meeting of the 1945–46 series on Tuesday, April 2nd, at McMaster University. "Welding in Plant Maintenance" was presented by Melvin O. Monsler, Assistant Sales Manager in the Welding Sales Division of the Harnischfeger Corp.

"The Nonsense of Oldtime Conceptions," *he says*

LOOK, A. E., at a newtime discovery in fabrication of metal products that makes sense. This wheel, for example:

OLD

Wheel failed at less than 170 lbs. pressure.

NEW

No wheel Failure. Tire bursts at 340 lbs.

Streamlined and twice as strong

PRODUCT: Wheels for pneumatic tires. Stamped in two halves from 14-gauge steel. Thickness at center of rim reduced to 16 gauge due to deep draw.

OLD DESIGN: Riveted construction. When tested by inflating tire, wheels failed at less than 170 lbs. pressure.

NEW DESIGN: Welded construction. With same test, tire bursts at 340 lbs. Only change in wheel is spread of 9/32" between outer edges of rim. Wheel is streamlined.

WELDING: Two halves are joined by "Lincolnweld", the new Lincoln automatic shielded arc welder. Weld circumference 25 inches. *Welding time 10 seconds.* Floor-to-floor time 45 seconds per wheel.

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ARC WELDING

CHICAGO

The regular monthly meeting of the Chicago Section was held on Friday, April 19th, at the Peoples Gas Auditorium. This was in the nature of a Symposium on "New Aspects of the Oxyacetylene Processes." R. B. Woodruff of the Air Reduction Sales Co. discussed the subject, "Technique in Fusion Welding;" J. Hudson of The Linde Air Products Co. discussed the subject, "Powdered Metal Cutting;" A. F. Chouinard of the National Cylinder Gas Co. discussed "Oxyacetylene Burner Design and Application." Each speaker discussed his phase of the subject and immediately after the major talk, a question period took place.

CINCINNATI

The regular meeting of this Section was held on March 26th at the Engineers' Club. W. J. Campbell, General Electric Co., Schenectady, N. Y., discussed the factors which must be considered in the "Selection of Welding Processes." Fifty members and guests were present for the talk and discussion period and for the regular social hour with the customary Dutch Lunch.

CLEVELAND

The regular monthly meeting of the Cleveland Section was held on Wednesday, March 13th, at the Cleveland Engineering Society. Approximately 110 attended the dinner and 175 attended the meeting. The dinner speaker was Hollie C. Williams of the Ohio Bell Telephone Co., who spoke on the "Mysteries and Beauties of the Great Southwest." R. F. Helmkamp of the Air Reduction Sales Co. presented the technical address on "The Electronic Bloodhound."

COLUMBUS

The April meeting of the Columbus Section was held on the 12th at the Southern Hotel. F. L. Goldsby, Development Engineer of the Chicago Bridge & Iron Co. spoke on the subject, "Design for Welding."

DAYTON

The newly organized Dayton Section has held the following meetings:

January 30th—Approximately 70 members and guests were present to hear Walter J. Brooking of R. G. LeTourneau, Inc., speak on the "Economics of Arc Welding."

February 27th—A. R. Lytle of the Union Carbide and Carbon Research Laboratories presented "Pressure Welding" to approximately 75 members and guests.

March 27th—Mr. A. F. Chouinard of the National Cylinder Gas Co. presented a talk on "Flame Shape Cutting Processes." Approximately 90 members and guests were present. Refreshments were served after a short business meeting.

DETROIT

The Detroit Section and the Saginaw Valley Division held their March meetings on the 8th and the 14th, respectively. The program covered a sound color film, entitled, "Truck Ahoy." J. M. Diebold. Welding Engineer, G. M. C. Truck Division, General Motors Corp., gave the history and performance of "The Duck." Mr. Diebold was in charge of welding during the development of the "Duck." It involved all types of welding from stack cutting of shapes to resistance welding of the fuel tank.

The April meetings were held on the 11th and the 12th, respectively. "Fabricating Characteristics of Heat and Corrosion Resistant Alloys," was presented by Wm. R. Grunow, Sales Engineer, Allegheny Ludlum Steel Corp. A sound film, "Stainless Steel," and a sound color film, "Arc Welding Stainless Steel," were shown.

HARTFORD

The Hartford Section held its March meeting on the 21st at the Hotel Garde. Dinner at the Hotel preceded the meeting. R. T. Gillette of the General Electric Co., Schenectady, N. Y., discussed the subject, "Resistance Welding." Mr. Gillette's address was very well received.

LEHIGH VALLEY

The March meeting of the Lehigh Valley Section was held on the 4th at the Hotel Bethlehem. Walter J. Brooking, Director of Testing and Research of the R. G. LeTourneau, spoke on the "Problems of the Welding Engineer." Mr. Brooking pointed out that the functions of the welding engineer include choosing the correct process and equipment, among other things. Professor P. B. Eaton of Lafayette College gave an interesting Coffee Talk on "The Far East Question." The speaker has on-the-scene information on the subject.

The April meeting was held in Packard Auditorium, Lehigh University, Bethlehem, on Monday, the 1st. This meeting was jointly sponsored by the Engineers' Club of Lehigh Valley and the Lehigh Valley Section of the A.W.S.

The speaker of the evening was Norman L. Mochel, who spoke on the controversial subject, "Welding vs. Castings vs. Forgings." Mr. Mochel is Manager of Metallurgical Research for the Westinghouse Electric Corp.

Mr. Mochel confined his remarks to applications in the "heavy industry" field and briefly reviewed the good and bad features of weldments, castings and forgings encountered during wartime production.

LOS ANGELES

The March 21st meeting held at Scully's Cafe had as its principal speaker Hugo W. Hiemke who used as his subject "Welding Research for Merchant Shipping." Mr. Heimke is well qualified to talk on this particular phase of welding as he was a welding engineer for the Bureau of Ships and has done considerable research work on the ships for the Merchant Marine. The two main points brought out were to avoid brittle factor by a better training program and improve shipfitting to avoid notches causing tri-axial tension.

MARYLAND

The Maryland Section meeting was held on March 15th with dinner at the Engineers' Club. Mr. R. F. Helmkamp of Air Reduction Sales Co. spoke on "Recent Developments in Machine Gas Cutting."

MILWAUKEE

A Smoker was held by the Milwaukee Section on March 1st at the Ambassador Hotel. The evening was spent in general

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introductions, card playing and entertainment of a magical nature.

The regular meeting was held on March 22nd. The main speaker, Carl Underwood Manager of Welding Dept. of Northern Ordnance, Inc., Minneapolis, Minn., spoke on "Modern Welding Practices." His talk was accompanied by slides which illustrated the need of modern thinking in the art of welding.

NEW JERSEY

Walter Begerow, Development Engineer, Air Reduction Sales Co., Jersey City, N. J., presented a most interesting and instructive paper, illustrated by a comprehensive series of slides, sketching the development of mechanized gas cutting from its infancy to the modern shape-cutting machines, at the March 19th meeting of the New Jersey Section.

The program opened with an "Information Please" Session with J. Riley of M. W. Kellogg Co., Jersey City, as Chairman.

A film, "Arc Welding of Stainless Steels," was shown through the courtesy of the Allegheny Ludlum Steel Corp., Brackenridge, Pa.

NEW ORLEANS

R. J. Pass, Sales Director of the Tempil Corp., New York, spoke on "Tempil Technique Applied to Welding" at the March 6th meeting held at the Isaac Degado Trade School. The attendance at this meeting was small because of the Mardi Gras.

NEW YORK

The March meeting of the New York Section was held in the Engineering Societies Building on March 12th. Harry T. Herbst, Development Engineer of The Linde Air Products Co., New York, addressed the meeting. His talk introduced the latest data in the field of gas-shielded arc welding of ferrous and nonferrous metals.

Slides accompanied Mr. Herbst's talk and many of the members attending joined in discussion of this subject after his conclusion. This talk was one of the best of the current season, particularly as it brought up-to-date information on the topic.

NORTHWEST

"Welding Distortion" was the subject of Chas. H. Jennings' address at the April 3rd meeting held in the Coffman Memorial Union, University of Minnesota. Mr. Jennings is Engineering Manager, Welding Department, Westinghouse Electric Corp., Trafford, Pa.

NORTHWESTERN PENNSYLVANIA

The Northwestern Pa. Section held one of its most successful meetings on Wednesday, March 20th. The meeting was in the nature of a Question and Answer program.

S. V. Williams of the Struthers Wells Corp. acted as chairman of the program F. M. Bernard, Westinghouse Electric Corp., answered questions on electric welding; Ben Grimes of Air Reduction Sales Co. handled the questions relating to gas welding and cutting; Clinton Swift of Greenleaf Corp. specialized on problems of nonferrous metals; and R. H. Davies answered questions on electric arc welding with particular reference to automatic and Heliarc.

PHILADELPHIA

The regular monthly meeting of the Philadelphia Section was held on March 18th at the Engineers' Club, preceded by dinner. F. E. McAtee, Engineer in Charge of Welding, Chicago Bridge and Iron Co., Chicago, spoke on "Safety of Large Field Welded Pressure Vessels," which was very well received by the 150 members and guests present.

PITTSBURGH

The regular monthly meeting of the Pittsburgh Section was held on March 20th at the Mellon Institute of Industrial Research. Dinner was held at the Webster Hall Hotel. J. B. Whitlock, General Maintenance Engineer, The American Rolling Mill Co., Middletown, Ohio, spoke on "Welding as a Maintenance Tool."

PORTLAND, OREGON

The tenth meeting of the Portland Section was held in the Mallory Hotel, on Tuesday, March 19th.

H. O. Westendarp, head of the Electrode Division of the General Electric Co., discussed the A.W.S. electrode specifications.

Joseph Holt, Welding Consultant and co-speaker of the evening, spoke on his theories of controlling distortion by proper welding sequence and illustrated the basic principles of heating to correct distortion.

A most interesting question and answer discussion was cut short in order to close by midnight.

PUGET SOUND

March dinner meeting was held on the 26th at the Engineers' Club, Seattle. Myron D. Stepath, Civilian Welding Engineer, United States Naval Base, Bremerton, Wash., spoke on the topic, "Welding Headaches—Their Causes and Cures."

A sound film, "New Horizons in Welding," was shown through the courtesy of the Harnischfeger Corp.

ROCHESTER

Monthly meeting of the Rochester Section held on April 4th at the University of Rochester. Dinner at the Powers Hotel preceded the meeting.

D. C. Smith, Chief Metallurgist, The Harnischfeger Corp., Milwaukee, Wis., spoke on the subject "Electrode Coatings —Their Development and Their Effect on Welding."

SAINT LOUIS

The St. Louis Section's March meeting was held at the Engineers' Club on the 8th with F. E. McAtee of Chicago Bridge and Iron Co. as the principal speaker. His subject was "Safety of Large Field-Welded Pressure Vessels."

The meeting was preceded in the usual manner with dinner at the Hotel Melbourne.

Eighty-one members and guests attended the technical session, which was of special interest to many fabricators and processing industries in this area.

Mr. McAtee's paper was essentially a treatment of the design and construction of "spheres." An excellent selection of slides was used to supplement the paper.

A lively session of questions from the floor was followed by refreshments.

SAN FRANCISCO

The San Francisco Section held a joint dinner meeting with the Northern California A.S.T.M. Section at the Engineers' Club, March 25th. The attendance was 99, of which 55 were A.W.S. members and guests.

In a short business meeting Chairman Leo Berner called on Frank A. Longo who presented the nominating committee's selections for Section officers for the coming year.

Mr. Dozier Finley, District A.S.T.M. Chairman, presented their National Executive Secretary, C. L. Warwick, who outlined the current activities and postwar aims of their society.

Speakers Table at San Francisco Section March 25th Dinner Meeting

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BLUE DEVIL ELECTRODES
(Recommended wherever weld metal of high quality is desired)
USED ON THIS PLANT YARD PIPE JOB!
CHAMPION Blue Devil Welding Electrodes E-6010 represent the most advanced development of the shielded arc type with a high over-all deposit efficiency obtained due to minimum splatter. Excellent penetration makes the Blue Devil especially satisfactory for welding rusty and dirty steel and for field work. For an all-position electrode of outstanding characteristics in construction of ships, bridges, buildings and all types of steel structures—use CHAMPION Blue Devil Electrodes.
Metallurgical tests make CHAMPION WELDING ELECTRODES the leading choice of fabricators who insist upon uniformly satisfactory results and increased production.
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ELECTRODE HOLDERS
THE CHAMPION RIVET COMPANY
WELDING ELECTRODES

THE CHAMPION RIVET COMPANY

CLEVELAND, OHIO — EAST CHICAGO, IND.

The speaker of the evening was J. R. Townsend, President of the A.S.T.M. and Director of the Bell Telephone Testing Laboratory. His subject was "Materials Engineering." Mr. Townsend reviewed many of the problems in the research and development of materials for the varied requirements of their industry. He stressed the importance of materials research to the present-day operating company. One interesting phase of their work, Mr. Townsend mentioned, was the study of the effects of climatic conditions on materials. He went on to show how this knowledge proved of value during the war. He concluded with an outline, illustrated with colored slides, of his recent observations in Germany, of manufacturing plants for wire and cable and other communications materiel.

SOUTH TEXAS

W. G. Gumm, District Engineer for The Linde Air Products Co. addressed the March 15th meeting of the South Texas Section, held in Houston. Mr. Gumm's subject for the evening was "Unionmelt Welding—What It Is and How It Is Used." During the course of the discussion the speaker explained the fundamentals of this process of automatic welding. Special adaptations of the equipment for welding irregular contours and for making fillet welds were shown in slides and discussed by Mr. Gumm.

SYRACUSE

The Syracuse Section held its regular monthly meeting on Wednesday, April 10th, at the College of Applied Science, Syracuse University. James E. Norcross of the Arcos Corp., Philadelphia, Pa., spoke on the subject, "Arc Welding of Stainless Steels." Mr. Norcross also presented a very interesting and highly instructive color film on "Arc Welding of Stainless Steels."

TIDEWATER

The Tidewater Section held its March meeting on the 12th at the Fleet Reserve Hall, Portsmouth, Va. James C. Powers, Jr., representing Handy and Harman, presented an interesting and instructive lecture on "Present-Day Uses of Low-Temperature Silver Brazing Alloys and Their Possibilities in Postwar Application."

The April meeting held on the 9th was addressed by Mr. Fitch Cady of the Chicago Bridge and Iron Co., Chicago, who spoke on "Distortion in Welded Structures." This subject is of much interest to welders and designers for welding, as it is one of the most important factors in welding structures.

TOLEDO

The March 12th meeting of the Toledo Section was somewhat unusual, because it covered a subject which heretofore was not given much public discussion. The interest ran high as could be seen by the large attendance, with out-of-town guests from as far away as 160 miles.

Tom Crawford, Consulting Engineer of Youngstown, Ohio, gave a very complete talk on the history of "Electric Tube Welding." He covered the period from the early blacksmith type butt weld up to the present day. Mention was made of early as well as of more modern patents and methods as used in this process.

Immediately following this discourse came the second part of the subject, "Applications of Welded Steel Tubing." This was very well presented by Harold S. Card, Educational Director for the Resistance Welder Manufacturers' Association.

The Tom Crawford-Harold Card team presented a well-balanced and capable speaker combination on the subject of welded steel tubing.

Slides were used and some of them presented interesting and unique applications where welded steel tubing proved its superiority in many ways.

WASHINGTON

The March meeting of the Washington Section was held in the Potomac Electric Auditorium on Tuesday, the 26th. F. Emery Garriott, Development Manager, Ampco Metal, Inc., was the speaker and his topic, "Welding of Copper and Copper Base Alloys."

This was the most authoritative exposition of the subject heard in Washington and an unusually large turnout was on hand to receive it. The talk was well illustrated with slides showing the practical applications of the processes. Following the talk, an Ampco film, "Golden Horizons," was shown. This unusual color film, tracing the history of bronze, was produced and acted entirely by Ampco personnel.

WESTERN NEW YORK

Leon C. Bibber of the Carnegie Illinois Steel Corp., was the guest speaker at the March 29th meeting of the Western New York Section held at the 40 & 8 Club, Buffalo. Dinner preceded the meeting. Mr. Bibber's subject, "The Various Welding Processes and the Relation Between Them," was received with interest by the eighty members and guests present.

WICHITA

The Wichita Section held their regular monthly meeting on March 6th at the Broadview Hotel. R. T. Gillette of the General Electric Co. was the speaker of the evening and his subject was "Resistance Welding." Mr. Gillette stressed the importance of proper design and machine setup in production welding. At the close of the lecture the speaker answered questions from the floor and a lively interest was shown in the resistance welding of dissimilar metals.

Annual Meeting—American Welding Society

Nov. 17-22 Atlantic City

Hotel Ambassador

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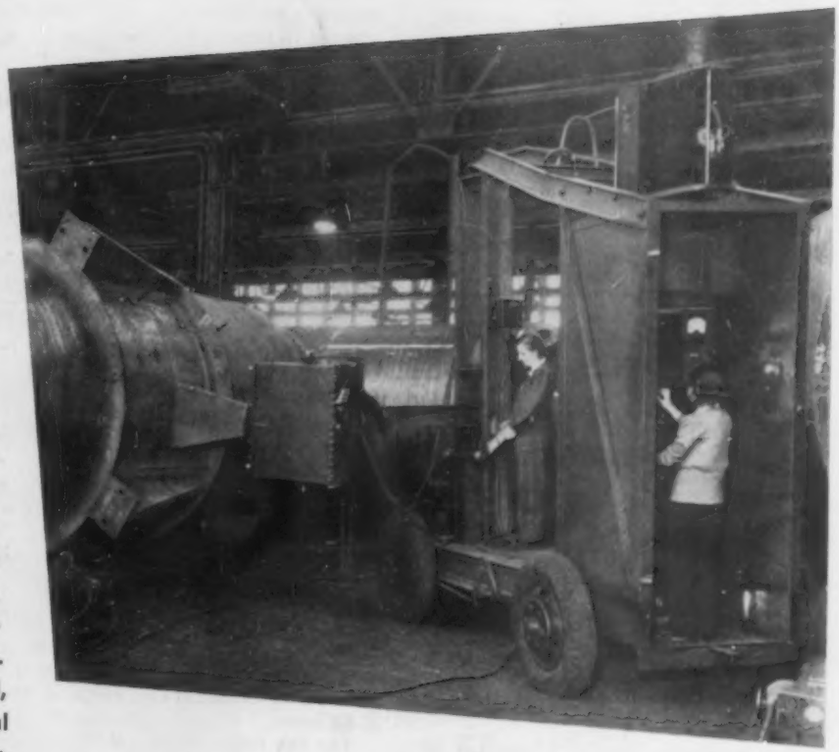
Maybe demands still exceed your production capacity . . . Maybe they will for some time to come . . . Maybe.

But keener competition lies ahead. That means a greater-than-ever accent on quality. To meet this challenge, forward-looking users of welding are relying on radiography . . . mandatory or not. By insuring quality through x-ray inspection—G-E X-Ray in a majority of cases — they minimize the "maybe" in their postwar future.



Rapidly and non-destructively, x-ray provides proof of a weld well-done . . . Positive proof, because even minute defects have no concealment when welds are radiographically tested. Proper x-ray equipment enables you to handle any job better—serves as a guide to better technics—is an expediter, teacher, cost-cutter and prestige protector. And in the complete line of rugged, highly precise G-E X-Ray Industrial Units is proper equipment for your particular requirements.

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GENERAL ELECTRIC X-RAY CORPORATION

ABSTRACTS OF CURRENT WELDING PATENTS

Prepared by V. L. Oldham

Printed copies of patents may be obtained for 10¢ from the Commissioner of Patents, Washington 25, D. C.

2,395,690—Welded Pressed Metal Landing Gear Strut; Donald W. Sherman, *Inventor;* Shorewood, Wis. Assignor to A. O. Smith Corp., Milwaukee, Wis. *11 claims.*

This patent covers a landing gear strut made from two longitudinally extending, complementary channels, the edges of which are abutted and welded together.

2,395,723—Welding Method and Apparatus; Erwin A. Chmielewski, *Inventor;* Milwaukee, Wis. *20 claims.*

The patented welding process relates to the formation of a pure homogeneous metal free of blowholes and slag between spaced metal parts. It comprises approximately continuously advancing a highly heat conductive metal block along the space between the parts to be welded, substantially continuously depositing molten weld metal and flux in such space at a sufficiently high temperature so that the weld metal rejects the slag and lies in a slag-covered puddle between the parts, and retaining the metal block adjacent to the molten weld metal to congeal the slag at the surface of the puddle. The block is removed as soon as the slag has formed a skin capable of retaining the molten metal behind it so that such metal cools in a normal manner.

2,395,977—Spot Welding Apparatus; Charles W. Sidney, *Inventor;* Summit, N. J. Assignor of one-half to The E. F. Hauserman Co., Cleveland, Ohio. *6 claims.*

This apparatus includes a plurality of spaced pairs of electrodes, a stationary contact for each electrode with equal impedance leads connecting the contacts to the electrodes, a movable transformer with rollers forming secondary terminals, and track means on which the rollers travel. The track means has pairs of contacts that connect to corresponding pairs of electrodes. Further means for maintaining selected pairs of electrodes in contact with the work while current is passed through such electrodes complete the machine.

2,396,002—Welder; George J. Frischmann, Queens Village, and Carl F. Brunner, Woodhaven, N. Y., *Inventors.* Assignors to Metropolitan Engineering Co., Brooklyn, N. Y. *14 claims.*

In this patent, an electric welder including a base, posts extending from and slidably mounted in the base, and a plate for carrying an electrode secured to the posts above the base, is shown. Pressure-actuated means are connected to the posts below the base for moving the plate toward and from the base, which is adapted to carry an electrode.

2,396,239—Welder's Shield; Edward R. Beck, *Inventor;* Salt Lake City, Utah. *15 claims.*

A welder's shield, that is pivotally supported on a wearer's head and is adapted to be moved by a shake of the head is covered in this patent. A spring mechanism is associated with the shield support to cushion the jar of downward movement of the shield and to facilitate upward movement of the shield.

2,396,452—Protractor Welding Jig; William Widmark, Duluth, Minn., and Albert H. Brownlee, Superior, Wis., *Inventors. 1 claim.*

This patented jig includes a base with an adjustable work holding member on it, and an upright support which pivotally mounts a protractor and guide arm for angularly positioning a member to be associated with the work secured to the base work holding member.

2,396,604—Welding Flux for Magnesium Alloys; Hans A. Reimers, *Inventor;* Midland, Mich. Assignor to The Dow Chemical Co., Midland, Mich. *3 Claims.*

The flux primarily comprises by weight a mixture of from 25 to 50% calcium chloride, from 20 to 65% potassium chloride, and from 5 to 40% sodium chloride and has a melting point below 600° C. The flux also has from 2 to 6% by weight of one of several metal fluorides in it and is substantially free of heavy metal salts.

2,396,765—Torch; George L. Walker, *Inventor;* Jersey City, N. J. Assignor to Air Reduction Co., Inc., New York, N. Y. *2 claims.*

A torch tip is covered in the patent and such tip has a plurality of jet passages leading to its burner end and two axially spaced distributing chambers formed at its feed end. The rearward face of the rear chamber connects to a gas inlet and the forward chamber connects to the jet passages. Communicating passages are formed between adjacent surfaces of the distributing chambers with the passages opposite the gas inlet being smaller than the other communicating passages.

2,396,870—Hand Electric Welding Tongs; James Saul McLean, *Inventor;* Oakland, Calif. *6 claims.*

The patented device for securing welding rods has a fixed jaw on the holder frame and a link operating member for a sliding jaw that is received in a channel provided in the frame.

2,396,968—Torch for Welding Thermoplastic Material; William M. Phillips, Jr., *Inventor;* Detroit, Mich. Assignor to The Udylite Corp., Detroit, Mich. *2 claims.*

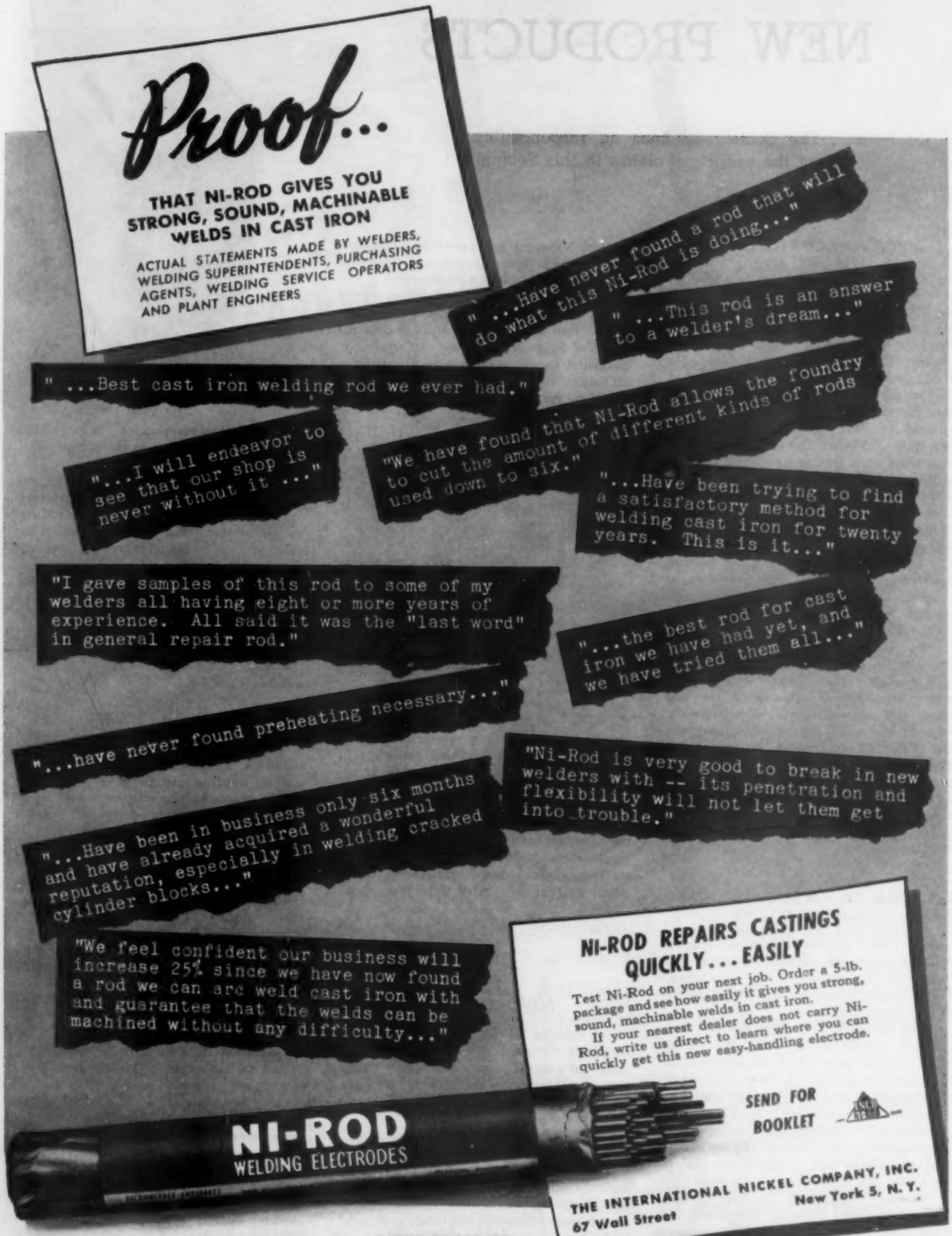
This torch produces a hot gaseous blast and has an elongate combustion chamber which has combustible gas fed thereto, and an elongate casing surrounding the combustion chamber and having a combustion-supporting gas fed thereto. The combustion-supporting gas flows through the casing to the combustion chamber in counter flow to the flow of gases through such chamber so as to withdraw heat therefrom before the gases flow from the torch.

2,397,252—Electric Arc Welding Handle; Charles M. Egan, La Mesa, and Carl H. Ledford, National City, Calif., *Inventors. 1 claim.*

The patented welding handle has a tubular, insulated handle member which slidably receives a conductor connector fitting therein. An insulated extension member is mounted on the connector fitting, extends out from the handle member, and adjustably carries a welding rod holder.

2,397,263—Resistance Welding Apparatus; Frank B. Hunter, La Canada, and James C. Arnold, Los Angeles, Calif., *Inventors.* Assignors to Adel Precision Products Corp. *4 claims.*

The electrodes in this resistance-welding apparatus are provided with means for holding two parts in engagement with each other and with the electrodes. The parts each carry sleeve means capable of telescoping into each other to form a chamber enclosing the electrodes and parts, and liquid coolant is supplied to such chamber to submerge the parts and cool them as they are welded together.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" ...Have never found a rod that will do what this Ni-Rod is doing..."
" ...This rod is an answer to a welder's dream..."
" ...Best cast iron welding rod we ever had."
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Test Ni-Rod on your next job. Order a 5-lb. package and see how easily it gives you strong, sound, machinable welds in cast iron.
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NEW PRODUCTS

The Society assumes no responsibility for the validity of claims in this Section

A NEW FLUX-COATED BRONZE WELDING ROD

A new flux-coated bronze welding rod for application by the oxyacetylene process has been developed by The Linde Air Products Co., Unit of Union Carbide and Carbon Corp. Known as Oxweld No. 25M patented flux-coated bronze rod, this new rod automatically combines all the superior properties of the familiar Oxweld No. 25M bare bronze rod with correct fluxing. When the rod is made, it is precoated with flux in proper proportion to its size. This coating consists of Brazo flux plus a nonactive binder that does not affect the weld. It adheres firmly to the rod, melting down into the molten puddle without burning off ahead of the rod. The rod can be heated and bent without destroying the coating. In addition, the coating is not affected by weather conditions.

Oxweld No. 25M flux-coated bronze rod speeds up the welding operation and makes it easier to produce welds of uniformly high quality. The operator can give his entire attention to depositing the rod metal and controlling the molten puddle without the usual delays of dipping the end of the hot rod into the flux container. The flux melts into the weld continuously and in the right quantities, leaving no wasteful residue on the face of the weld. Thorough tinning, essential to good bronze welding, continues without interruption.

BRAZING RODS FOR MAGNESIUM AND ALUMINUM ALLOYS

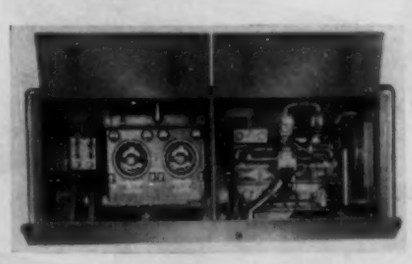
A new and improved type of brazing rods for use on die cast, white metal and aluminum metals has been developed. These two rods are known as WOW #1 and #2 Acetylene Rod.

WOW #1 is a 700° brazing rod for extra strength and WOW #2 is 500° for use on white metals where low temperature is necessary. Both rods have the following advantages over any type we have encountered to date: both working temperatures are far below the breaking down temperature of the metals the rods are used on; the ease of applying the rod to the work; the speed that can be used due to the ease of applying; absence of porosity in the weld deposit; practically all brazing can be done without flux.

TWO-OPERATOR GAS DRIVE WELDER

The Hobart Brothers Co., Troy, Ohio, has just developed a 2-operator gasoline engine driven arc welder by placing two of their 300-amp. generators on a common shaft, which are supplied with separate excitation from a common exciter.

This double unit is directly connected to an 8-cylinder Chrysler industrial engine. Two operators can work independently of each other, since the engine is governed to maintain constant speed for all loads. A paralleling switch is also provided to turn the unit effectively into a single-operator 600-amp. unit.



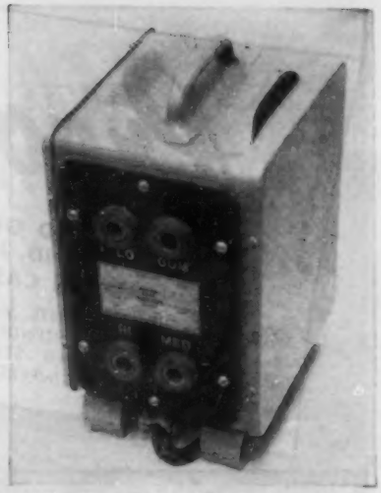
Because welding is inherently an intermittent load, 2 units can be connected to one engine to give a higher over-all economy. The net idle running time of the engine is reduced. . .also engine service time, maintenance, etc., are reduced.

The generator paralleling switch also gives the setup more flexibility, as it results in a welder of 600-amp. capacity for heavy welding and cutting duty. This paralleling unit effectively doubles the welding range of the conventional single-operator unit and is of great value on construction and maintenance work where a great variety of welding is experienced.

PORTABLE BRAZER

For making lap joints in copper strap, attaching terminals to cable, brazing coil ends and general copper smithing work, a new portable 5-kva. brazer weighing only 30 lb. is announced by the Westinghouse Electric Corp.

The new brazer, which requires connection to a 220-v. source, consists of a transformer, voltage selectors, controls and carbon-tipped tongs. Alternating current from an adjustable voltage transformer passes through the tongs and parts to be brazed, raising the temperature to a point at which the brazing alloy melts. The brazing alloy may be applied in the form of a rod or in ribbon form. Three outlets are provided on the control panel for 8, 6 or 4 v. Voltages are easily and quickly adjusted by inserting bayonet plugs attached to the brazing leads into



plainly marked receptacles. A foot switch with pilot cable serves as the primary control switch.

For use with air-cooled tongs, the new brazer is supplied with a handle for carrying. The 30-lb. unit is cooled by natural air circulation. Air enters bottom of the case and is expelled through louvered openings in the top.

Further information on the new 5-kva. portable brazer may be secured from the Westinghouse Electric Corp., Box 868, Pittsburgh 30, Pa.

POWDER WELD

A challenge to producers of powdered materials and promise of some revolutionary welding and metal or plastic surfacing processes are seen in a new flame tool recently announced by the Powder Weld Co., 419 Kent Ave., Brooklyn, N.Y. The equipment consists of a torch, made in the general outlines of an ordinary welding torch, but having a special patented nozzel and 16 independent controls, many of them at the handle of the tool; a control box with air and gas pressure regulating valves and a canister from which powdered materials are fed through the flame. The flame is generated and controlled by preselected combinations of gases and air.

Known as Powder Weld, the equipment is described in a bulletin issued by the maker as "a new method of welding, brazing or surfacing with infinite compositions of powdered materials." It was first shown at the recent metal show in Cleveland, where it created something of a sensation. Demonstrations of welding and hard surfacing were conducted, indicating interesting possibilities for the tool in welding or brazing with mixtures of powdered metal and dry fluxes. Many varieties of superhard metals were successfully applied to illustrate the speed and depth of coating possible in a hard facing. Welding applications are restricted only by limitation in the variety of powdered metals now available which are suitable for welding.

Outstanding feature of the equipment is the completeness of control over all oper-

Announcing a new

ANACONDA COPPER WELDING ROD "372"

FOR OXY-ACETYLENE WELDING OF DEOXIDIZED COPPER

THIS new patented Anaconda Welding Rod, containing approximately 98.85% copper, was developed by The American Brass Company for the oxy-acetylene welding of Deoxidized Copper. It deposits weld metal that is sound, ductile, and of high strength. Welds made of it on Deoxidized Copper develop the full strength of the annealed base metal without the costly hammering or working usually required to develop this maximum strength when ordinary copper welding rods are used. The composition of the rod meets the requirements of designers of equipment for service in corrosive conditions where it is essential that both base metal and weld metal be of high copper content. Information on welding practice when using Anaconda Copper 372 Welding Rods will be mailed on request.

46195

ANACONDA
(from mine to consumer)

Anaconda

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In Canada: ANACONDA AMERICAN BRASS LTD.,
New Toronto, Ont.

ating conditions, enabling as operator to achieve the following results: precise control of the amount of flux to be used with the metal or alloy. Mixture is predetermined and accurately weighed before use; accurate control of the amount of the mixture used per minute or per inch of weld or braze. This control is right at the operator's finger tip: accurate control (at the torch handle) of the flame temperature and atmosphere, by regulating the amount of fuel gas-oxygen mixture and the addition of processing gas around the flame as desired. The cooling or processing gas is controlled independently of the fuel and of the projecting gas: accurate control of the temperature of the metal, alloy, plastic or other material projected, employing the controls above mentioned: accurate control of the temperature of the target, or work surface, by increasing or decreasing the amount of flame, and proportioning the projecting gas (and material) and the processing gas. Both target and material temperatures are controllable all the way from the melting temperatures which give high-quality metal bonded hard surfacing or welding results to "dry" application of metal similar to ordinary metal spraying.

Typical applications for which Powder Weld is described as being suitable are hard facing, surfacing with plastics or synthetics enamels, brazing with powdered alloys, welding with powdered metals, rod welding with projected fluxes, controlled atmosphere welding, conventional torch and rod welding, metal spraying of all kinds. The Powder Weld bulletin illustrating and describing the equipment is available on request.

SHAPE-CUTTING MACHINE

The first postwar model of an Oxweld oxyacetylene shape-cutting machine, the CM-15-36, has been announced by The Linde Air Products Co., a Unit of Union Carbide and Carbon Corp.

The new machine has been designed to do precision cutting on work of intermediate size, which formerly could be done only with a large machine. For the first time on any Oxweld shape-cutting machine, an attachment is available for this machine which makes it possible to mount the blowpipes on both sides of the tracing table. This feature makes the machine particularly adaptable to high-production setups by permitting the cutting of identical shapes simultaneously from plates on both sides of the tracing table. The attachment can also be used to great advantage in eliminating "down time," since plates can be put into position on one side of the machine while cutting is being done on the other.

All types of shape cutting performed with larger machines are possible with this machine within its 36-in. transverse working range. The longitudinal working range with the standard table is 100 in. and this range can be extended indefinitely by adding frame and table top sections.

The CM-36 machine, selling at a price considerably below that of larger machines, will be of primary interest to those whose work falls within its range.

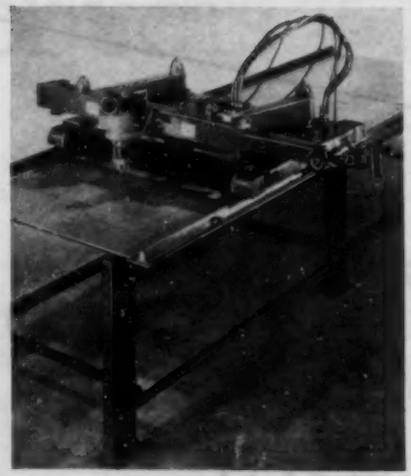


Fig. 1—A New Cutting Machine to Do Precision Work on an Intermediate Scale.

The carriage of the CM-15-36 is made of cast aluminum to provide the combination of light weight and rigidity required for accurate shape cutting. Two free-moving pivoted arms mounted on the free-rolling carriage give blowpipe motion if any direction within the limits of the work area of the machine. The carriage travels on a track firmly mounted on a sturdy table frame fabricated from structural members. A flat one-piece aluminum plate, 42 x 144 in. long, supported on the frame between the rails of the track, serves as a table surface upon which the drawing or templet to be traced is placed.

The tracing head, powered by a 110-v. universal motor, provides smooth and accurate travel of the blowpipe. A simple eddy-current type speed governor gives an infinite variation of speed—from $3\frac{1}{2}$ to 28 in. per minute—which is indicated to the operator on an easy-to-read speedometer.

The machine, as shipped, is equipped for either mechanical tracing with strip templet or hand tracing. A magnetic tracing unit is available as an accessory for use when maximum precision in repetitive production shape cutting is desired. Straight-line cutting guides and a circle-cutting attachment for automatically cutting circles $1\frac{1}{2}$ to 36 in. in diameter, are supplied with the machine. The blowpipe holder may be tilted to an angle of 45° from the vertical, to permit making bevel cuts. By use of supplementary blowpipe holders, mounting bracket and bar two blowpipes may be mounted on the same side of the machine for simultaneous cutting of identical shapes.

This versatile machine fills a long-felt need for an accurate shape-cutting machine of moderate price for work up to 36 in. wide.

MINIATURE WELD POWER UNIT

Electronically controlled welding with all its advantages is now available in the low-price field with the announcement of the Raytheon Miniature Weld Power Unit produced by Raytheon Manufacturing Co. of Waltham, Mass. Raytheon Miniature Weld Power equipment does away with the necessity for the human element of control of the quality of the weld. Production is greatly increased with more uniform results by unskilled help.

Raytheon, as one of the country's major radio and power tube producers, first used the miniature welder on its own production lines. The remarkable performance in welding all types of diversified metals required in tube construction, under the most precise values of welding pressure and energy, culminated in the commercial production of electronic welders.

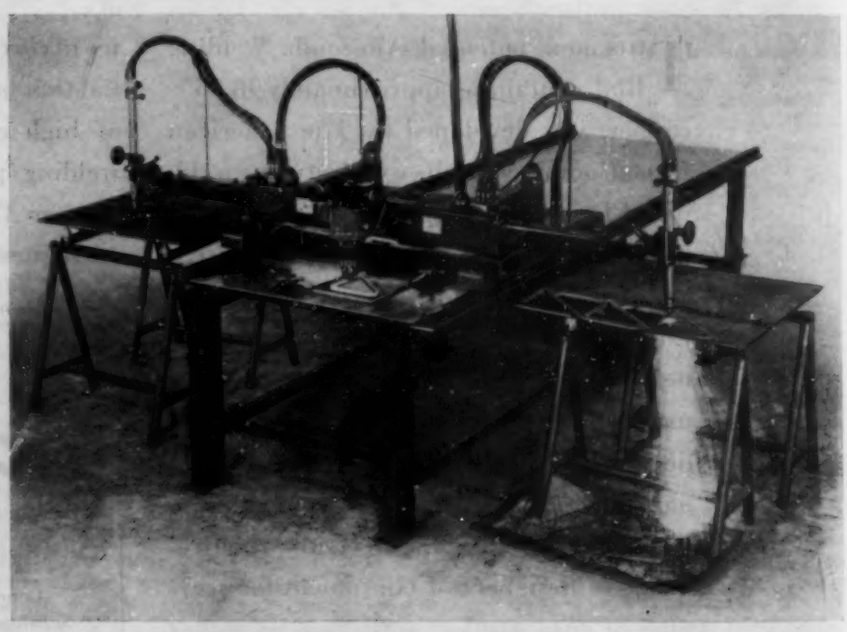
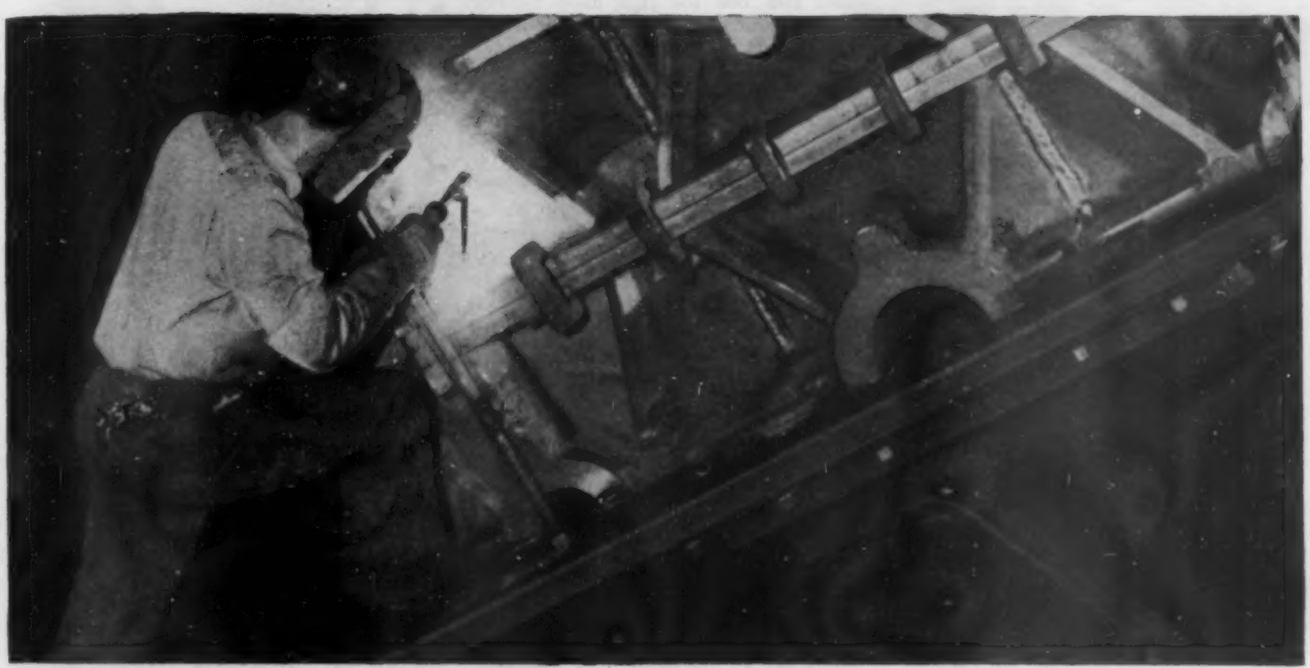


Fig. 2—Shown Above Cutting Gusset Plates Is a New Shape-Cutting Machine Designed to Do Precision Work on an Intermediate Scale

MUREX FHP

"Hot" Electrodes



For Fast Downhand Welding of Heavy Equipment

Thoroughly proved in a wide variety of applications, Murex Type FHP electrodes are outstanding because of the high currents at which they operate and the excellent, sound weld metal they produce. They are especially suited for deep groove welding, the making of both positioned and horizontal fillet welds and other downhand work.

The rapid deposit rate and good penetrating properties of these rods have helped to reduce welding costs and improve the quality of welds used in fabricating large frames, housings and bases for machine tools, tank and pressure vessels and other heavy units. In addition to being easy to handle, Type FHP may be used on either direct current, straight or reverse polarity, or with alternating current.

More complete information about these and other Murex electrodes may be obtained by writing to the Metal & Thermit office nearest you. Our representatives will be pleased to show how easy this Murex FHP electrode works and how well it performs on heavy jobs.

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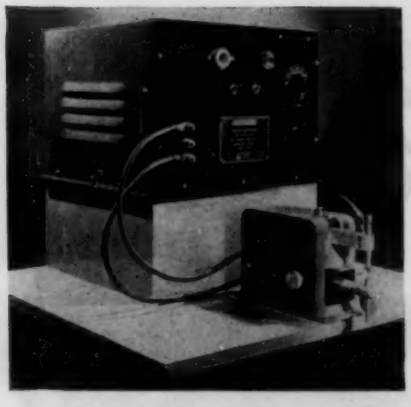
MUREX ELECTRODES



The unit is small, measuring 9¾ in. high, 13 in. wide and 13½ in. long, and is capable of producing 60 to 120 welds per minute on a total thickness of 0.035 in. for practically all metals and principal alloys, or combined pieces being welded of 0.060 to 0.070 in. in cross wire welding.

Installation is so simple that it may be made by anyone. The instrument need only be plugged into the most convenient source of 110–125-v., 60-cycle output. Current drain averages only 3 amp. at maximum setting.

The power output into the weld can be varied. A voltage adjustment control varying the capacitor charging voltage from 750 to 1500 v. and a three-position capacitor switch by which values of 14, 28 or 56 microfarads can be attained, are mounted on the front panel of the control unit.

After having once been adjusted for a given power and time cycle for certain material and thickness, the Raytheon Miniature Weld Power Unit requires no further adjustment to produce constant uniform welds. The materials to be welded are placed between the electrodes and the energy stored in the electric storage system is applied to the pieces to produce a weld.

The welding head supplied with this unit is designed to give a preset pressure to the material being welded and as soon as the pressure is applied the power is triggered by a microswitch mechanism located in the head, thereby controlling the applied pressure and cycling of the weld power.

Metals that may be welded by the Miniature Weld Power include iron, aluminum, copper and copper alloys, nickel flat and wire, nickel alloys, tantalum, platinum sheet or wire, tungsten sheet or wire, gold sheet or wire, constantan sheet or wire, stainless steel and alloys of the above materials.

Raytheon's Miniature Weld Power has many applications in industry, particularly in the manufacture of small jewelry, electrical equipment, electrochemical apparatus and radio parts. The application of welding to many products heretofore restricted by the physical limitations of the medium is now made possible with the Weld Power equipment.

Annual Meeting
A. W. S.
Nov. 17–22

DUAL ULTRA-SPEED ASSEMBLY WELDS FENDERS

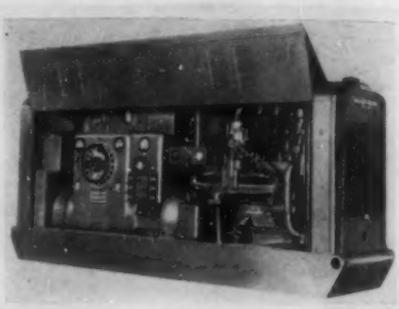
The coordinated production of both right-hand and left-hand fenders at 150 units per hour has been simplified by a leading manufacturer of auto bodies through the use of a duplex ultra-speed welding machine, designed and built by Progressive Welder Co., 3050 East Outer Drive, Detroit 12, Mich. The machine has two welding positions—one for left-hand and one for right-hand fenders. Either position can be operated individually, or both right- and left-hand fenders can be welded simultaneously. Thus, two operators can maintain a continuous supply of matched fenders at the rate required by the final assembly line. In this machine the dust shields are welded to the 18-gage steel fender.

The machine is so designed to permit it to be split in two sections and the halves moved to separate locations if desired. Each side has its own welding transformer, ultra-speed current distribution switch, timing circuit and contactor. One hydraulic power unit furnishes welding and clamping pressure to both sides of the duplex machine. Thus only an additional hydraulic power unit need be supplied to operate the two halves individually. This design results in a sizable economy in equipment and floor space in addition to flexibility.

Three types of welding guns are incorporated in the machine: a standard direct action type, a bell crank type to provide the greater clearance required at several points for easy loading of the parts and a floating type gun, mounted on the main table, to provide the extreme clearance required to clear the major flanges of the assembly. Both integral loading fixtures are provided with adjustable positioning arms for accurately locating the headlamp mounts, for a wide range of fender lengths. The accurate location thus obtained and the clamping action provided by the simultaneous impingement of the welding guns on the work results in the production of practically identical assemblies.

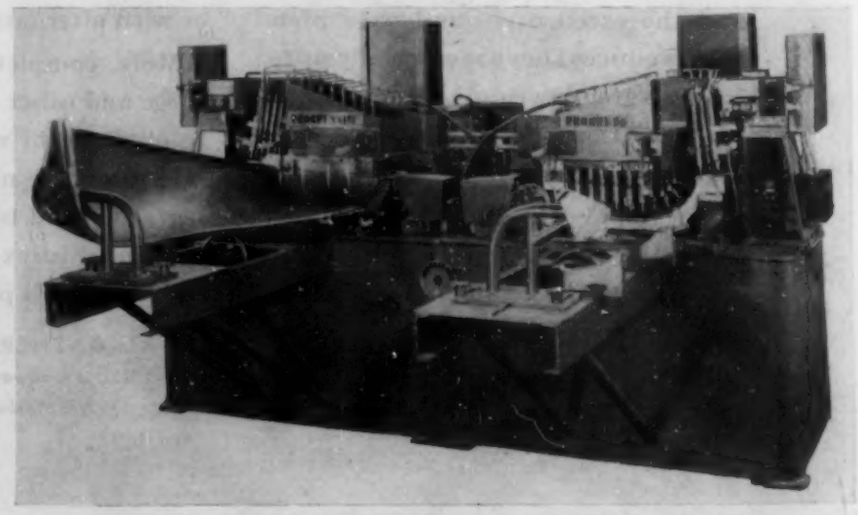
300-AMP. GASOLINE-DRIVEN ARC WELDER

For many years, The Hobart Brothers Co., Troy, Ohio, has been building gasoline-driven arc welders with inbuilt auxiliary d-c. generators of 115- and 230-v. capacities. These units are used as sources of auxiliary power.



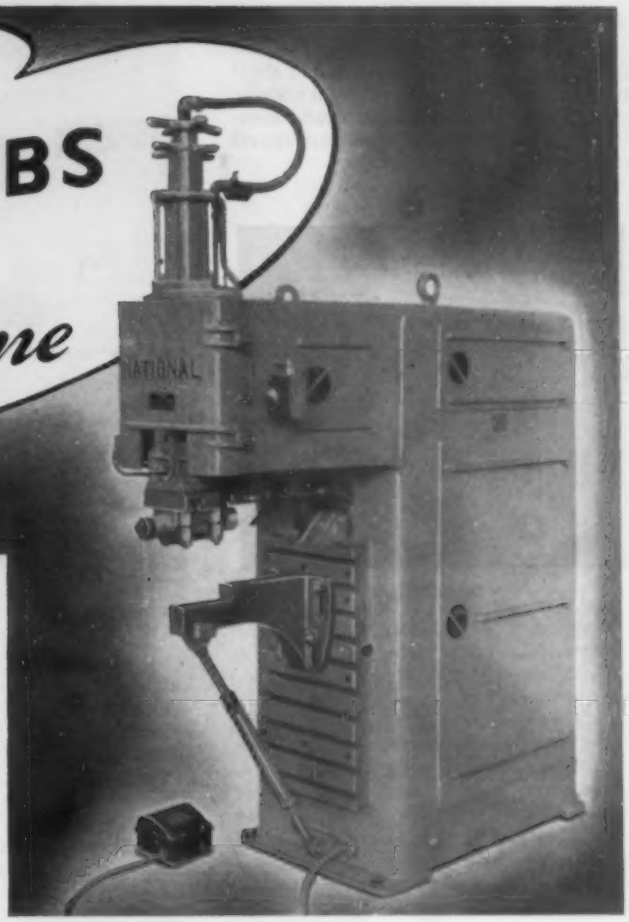
A new development is a 300-amp. gasoline driven arc welder with an inbuilt auxiliary a.-c. generator. This compact, high-performing design has resulted by taking advantage of the Hobart oversize separate exciter—using it to supply excitation to both the welding generator and the a.-c. generator. With the clever arrangement of connecting the stations and panel of the a.-c. generator, it is possible to furnish the following combinations of power simultaneously: 110 v., 60 cycle, single phase; 110/220 v., 60 cycle, single phase, 3 wire; 220 v., 60 cycle, single phase; 220 v., 60 cycle, three phase.

The panel provides receptacles and studs for connecting to the power required, an a.-c. voltmeter with dual scale, frequency meter and rheostat for controling the a.-c. voltage. This auxiliary a.-c. generator is available in two sizes, 6 and 12 kw. and complete details will be furnished by the manufacturer on request.



Coordinated Production of Both Right-Hand and Left-Hand Fenders at 150 Units per Hour Has Been Simplified by a Leading Manufacturer of Auto Bodies Through the Use of This Duplex Ultra-Speed Welder, Designed and Built by Progressive Welder Co., Detroit

Welding a VARIETY OF JOBS *on the Production Line*



Welding a variety of jobs calls for equipment capable of universal adaptability. NATIONAL has designed universal adaptability into its welders. Adjustments are quickly and easily made, and when once made they remain constant until another change is required to suit a specific job.

The equipment illustrated has adjustable operating stroke with retraction as well. A low inertia roller bearing upper ram is also provided facilitating the welding of alloy steels. The "T" slotted apron for lower knee mounting provides lower knee positioning adjustment through an extremely wide range.

Spot welding electrodes or projection welding dies can be applied to suit any desired welding job within the machine's electrical and mechanical capacity. The lower arm brace shown, is removable when lower arm clearances are required.

The electronic controls (tube contactor and sequence timer) are enclosed within the machine's base making the equipment a self contained unit which, if necessity arises, can be moved easily to any position in the Production Line.

Universal adaptability is the Keynote of NATIONAL design!

Illustrated above is a NATIONAL 100 Series Air Operated Press Type Combination Spot and Projection Welder (with welding electrodes and/or dies omitted) with frame enclosing electronic controls. The machine is one of a battery of 43 recently furnished one of the largest fabricators of sheet metal parts in this country for post-war production.

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District Offices: Montreal, Toronto, Ottawa, Kirkland Lake, Vancouver. Representation in Halifax, Winnepeg, and Edmonton.
Distributed in Canada by Rudel Machinery Company, Offices in Montreal, Toronto, Windsor, Vancouver

LEGGINGS

Developed to provide protection against heat, sparks, hot metal splashes and abrasives to legs and shins of industrial workers in foundries, around blast and open-hearth furnaces, welding, sandblasting and many similar jobs.

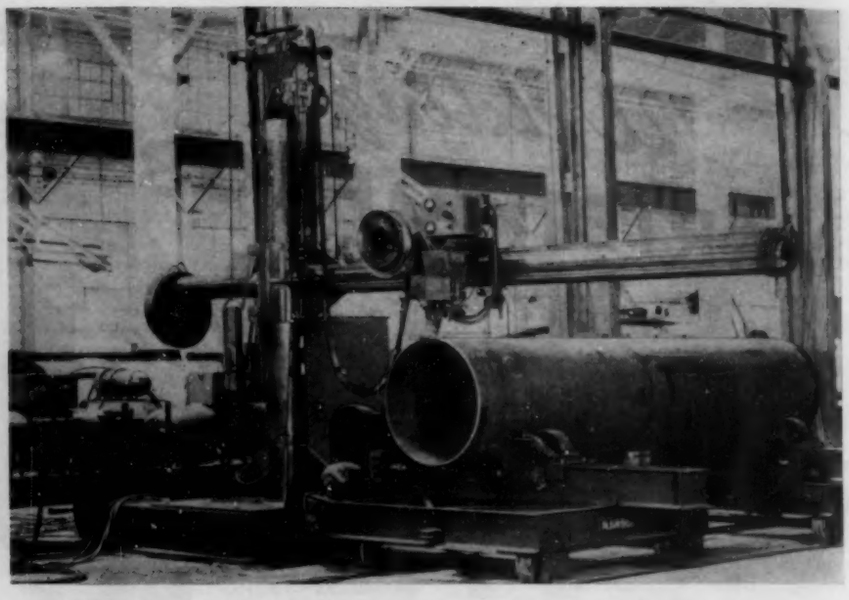
Body of legging is made from either Underwriters grade asbestos; grade 1 chrome tanned heat-resisting leather; fireproofed duck or impregnated synthetic duck. Inside front of legging is reinforced with heavy canvas and between this canvas and the body of legging are inserted two pieces of fiber for extra protection against splash, blowouts and impact. Top of legging is form fitting so as to leave no gaps.

A side stay of heavy gage nonrusting metal is securely fastened to legging to keep it in a firm, upright and comfortable position on the leg, and to provide proper adjustment to any leg size. An extremely long, noncurling, double chrome leather flare extends over entire foot and forms a perfect fit over top and side of shoe. All seams are first double sewn, then riveted at all vital points of greatest wear for reinforcement. Made by Safety Clothing and Equipment Co., 7016 Euclid Avenue, Cleveland 3, Ohio.

TURNING ROLLS FOR AUTOMATIC WELDING

Self-propelled turning rolls mounted on tracks, with the automatic head in a fixed position, for stepped-up automatic welding production on tanks and cylindrical objects of various lengths and diameters are used by the Struthers Wells Corp., in Warren, Pa. On circular welds, the weldment is set on the turning rolls and rotated, for longitudinal welds, the work is driven along the track, both at the desired welding speed. The work is thus positioned under the automatic head for all welding operations.

Self-propelled turning rolls consist of two parts, the electric power-driven turning rolls and the idler rolls without power, each mounted on separate carriages. The power drive serves a dual purpose. It rotates weldments for circular welds, and by shifting a clutch, the power is transferred to drive the work forward or reverse on the tracks for welding longitudinal seams. The individual rollers are equipped with tires of industrial truck type rubber to prevent bumping when longitudinal welds pass over the rollers.



Turning Rolls for Automatic Welding

The weight capacity of these new Ransome self-propelled turning rolls is 25 tons. The distance between the rollers is adjusted to accommodate diameters of work from 2 to 14 ft. The circumferential speed of the rollers, as well as the longitudinal speed of travel of the carriage is adjustable for welding speeds of 7 to 57 in. per minute. Remote control of starting, stopping and reversing both the turning rolls and track carriage, as well as remote speed control, is provided allowing the operator to manipulate these functions at his point of work.

Ransome Machinery Co., of Dunellen, N. J., a subsidiary of Worthington Pump and Machinery Corp., designed this new Size No. 1 Self-Propelled Turning Roll to provide the most economical manner of handling the welding fabrications of tanks and all circular work for automatic welding. It is the latest addition to Ransome's complete line of positioning and turning roll equipment for welding and work applications.

BRAZING FLUX

A new, superior flux for efficient brazing of aluminum (see illustration) with X716 wire has just been introduced by A. K. Mauk, 7501 Hamilton Ave., Pittsburgh 8, Pa. Designated as "Flo-Well" No. 2, it is equally useful in either furnace brazing or torch brazing aluminum. It can be applied easily by inexperienced workmen and will not solidify or deteriorate.

"Flo-Well" and X716 may be employed alone in brazing 61S and, in combination with hydrogen and oxygen, may be used in brazing 2S, 3S, 24S and 52S. The X716 wire can be obtained wherever aluminum is sold, or direct from A. K. Mauk.

The new flux is packaged in $^1/_2$- and 1-lb. glass jars for protection from moisture, and is also available in larger quantities. Free samples of both "Flo-Well" No. 2 and wire X716, together with complete directions for use, will be forwarded by the manufacturer upon request.

Illustration Shows Two Pieces of Aluminum Brazed with New Mauk Flux

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CUTTING TORCH

The new Gasweld Featherweight Cutting Torch, manufactured by the Wall Chemical Div. of Liquid Carbonic Corp., 3100 S. Kedzie Ave., is in production. The Gasweld Featherweight is designed for the user who needs a medium-sized cutting torch to do light metal cutting but occasionally needs to cut heavier materials as well.

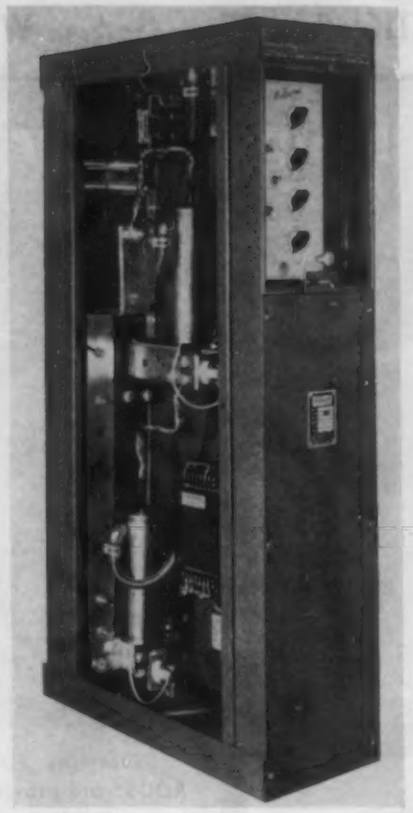
The Gasweld Featherweight weighs 2 lb., 2 oz.; its light weight and balance are intended to step up production by cutting down worker fatigue.

Only 16 in. from tip to butt of handle,

it is ideal for close-quarter work on sheet metal in pipe shops, scrap yards and garages. It has a ribbed brass handle for positive grip, and tubes of nickel-copper alloy in triangle assembly for strength and rigidity. Available with either 80 or 90° forged head, the Featherweight has a 1-piece tellurium copper tip.

RESISTANCE WELDING TIMER

The photo shows the new Model 120-75 type S.E. nonsynchronous timer-contactor



for resistance welders developed within the past three months.

There are two special and completely new features, namely:

1. Narrow construction (only $8\frac{1}{2}$ x 40 x 20 in.) can be mounted in minimum of space on either side welder.
2. Only two relays used. All sequencing relays previously used have been eliminated.

Additional features provide a glass cover on the door to provide dial visibility with cover closed and locked. A removable plug-in type timer panel which can be replaced with little loss of time. For wall mounting or floor mounting with leads entering either in rear or side of cabinet.

Additional information can be obtained by writing for Bulletin, Weltronic Co., 19500 W. Eight Mile Rd., Detroit 19, Mich.

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1944 Lecture—Pressure Welding by Dr. A. B. Kinzel, Vice-President, Union Carbide & Carbon Research Laboratories.

1945 Lecture—Selection of Steel for Welding, by Dr. S. L. Hoyt, Technical Advisor, Battelle Memorial Institute.

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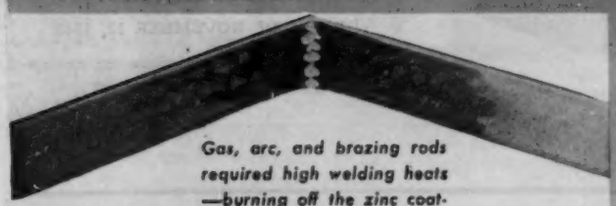
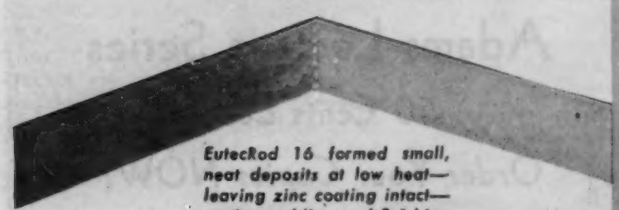


Gas, arc, and brazing rods required high welding heats —burning off the zinc coating—depositing large beads.



EutecRod 16 formed small, neat deposits at low heat— leaving zinc coating intact— cutting welding and finishing time 800%.

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1. Bond to base metals well below the base metal melting point. 2. Form exceedingly strong joints through surface alloying. 3. Give faster, better bonds at lower cost. 4. Avoid the dangers of stress and distortion characteristic of fusion welding and brazing.

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Please send me complete information on how to purchase a trial selection of 9 EutecRods for everyday use: also facts on EUTECTIC *Low Temperature* WELDING RODS and Fluxes. Dept. WJ-5.

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Company.....

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Everyday EUTECTIC *Low Temperature* WELDING RODS* are proving to be the best in production welding. Hundreds of manufacturers are finding their many advantages to be the deciding factors in bidding low on important jobs and getting the contracts.

Here is a typical report from Keller Metals, Inc. This company bid on a big air-conditioning contract and *got it!* With the use of EutecRod 16, they were able to cut production time and manufacturing costs to the bone.

"The job called for welding large panels and trays made of 18 gage galvanized iron. We tried several different rods, but the high welding heats required, oxidized the zinc coating, necessitating recoating after welding. In addition, the weld deposits were so large that they had to be ground down. These additional operations required too much time and made the cost of fabrication prohibitive.

"Then we tried EutecRod 16, applied with the oxyacetylene torch. With its use, we cut production time for one unit from 30 minutes to 5 minutes. The low heat of application did not affect the zinc coating. Also, small, neat fillets were obtained without grinding.

"With EutecRod 16, we obtained a sound, leakproof construction of high strength and smooth appearance at low cost, and we got the contract."

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